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Hospital Resource Management using Machine Learning during COVID-19

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Abstract: Covid-19 has become a well-known virus which gives us many challenges to face and survive nowadays. The second wave of virus greatly affected the lives of every age of people. Studies shown that young to matured generation suffered from its severity. The main challenge we face to manage resources to overcome from this pandemic with safety of people. The available data present that we were running out for resources during the crisis of second wave of Covid-19. Various authors had worked upon this problem to get proper solution. In this paper, we aim to present the literature survey and critical analysis of proposed solutions for hospital resource management during Covid-19 presented by various researchers. On the basis of our survey and critical analysis, we find out some future works those can be useful to improve hospital resource management in pandemic situations.

Keyword: Covid-19, Resource Management, Machine Learning, Deep Learning, Pandemic, Healthcare

1. Introduction

Coronavirus disease (COVID-19) is a communicable and infectious disease which contains SARS-Cov-2. In India the disease came into existence in 2019. Covid-19 disease originated from China. Some people who are Covid positive are symptomatic and some are asymptomatic [1]. Symptoms of Covid-19 include mild fever, Throat infection, body pain, cough, tiredness, loss of taste and smell. However, some people do not experience symptoms and get really severe and require medical attention. The people who are already suffering from other diseases like cancer, respiratory issues and diabetes are more likely to get seriously ill and are hard to get recovered even after getting medical support.

Covid-19 pandemic has shaken up the whole medical system. High demand of resources leads to critical shortages of Primary Hospital Resources [2] like beds, ventilators, space for admission and major supplies. Developing countries like India with over 138 Crores of population face a greater challenge. Therefore, Strategic planning of healthcare resources and proper utilization is very important aspect to prevent the spread of Coronavirus and to prevent deaths due to Covid.

Most countries have new guidelines for this pandemic and hospitals are following that for their own preparedness. In India, the first case on Covid-19 was found on 30th January 2020 and the government of India took it very seriously and restricted international travel, cancelled all the flights and imposed First full lockdown by third week of March 2020. The positive patients of Covid were sent from minimum 14 days quarantine which was very important at that time to stop the virus from spreading. Several reports from India, South Korea and Nepal focused on proper healthcare resource allocation which is very important for spread of Coronavirus. Focus area for preparedness will be: Healthcare Space Management [3], Healthcare Beds Management, Healthcare Ventilators Management.

In this research paper, we are going to analyse the different research papers that are relevant to our model and are useful for our domain. Various authors have presented their work in this field so we would like to summarize that. In next section of this paper

Literature Survey is given. Then Discussion is done and Research Gaps are shown. After that Research Challenges are given and finally Conclusion and Future work are mentioned.

2. Literature Review

Mortality Rate prediction for Covid-19 using SNN Models [4]. The main objective is to predict mortality rate for Covid 19 and estimate the future death cases in India due to pandemic. Firstly, RMSE value was found for the two datasets using 3 SNN models and was compared, if the RMSE value is lower it is the new predicted value otherwise error was found using NAR-NN time series forecasting model to predict the residual values and was added to the prediction value. The author used Generalized Regression Neural Network (GRNN), statistical Neural Network (SNN) method such as Probabilistic Neural Network (PNN), and Radial basis functional Neural Network (RBFNN). For both the datasets and respective SNN models spread value is estimated between (0-4) using the RMSE predicted values. Predicted curves are made for both standard and hybrid SNN. Death values are predicted for both D1 and D2 using PNN, RBFNN and GRNN [5]. The major limitations are: Most of the cases of Covid-19 were asymptomatic and the cases were not reported, Some Demographical and topographical were not included in these SNN models, this hybrid SNN-NAR-NN model is not that efficient for long-term mortality rate prediction. For increasing the prediction accuracy for the Covid-19 mortality rate prediction Recurrent Neural Network of Deep learning was used and other geographical and demographical factors which are not included in these hybrid SNN model will be used

CPAS: The UK's National Machine Learning-based Hospital Capacity Planning System for Covid-19. The main objective is to plan for the hospital capacity and Intensive Care Unit (ICU) beds capacity [6]. Different algorithms the author used for predicting the risk at individual level are: for imputation the author used GAIN algorithm, for feature selection the author used No selection algorithm, for prediction the author used XG boost algorithm and for calibration the author used isotonic regression algorithm. The author used the no. of patients hospitalized, database of research centre and no. of intensive care national audit, hospital episode & statistics community mobility reports. The main parameter is desired resolution, select the hospital, trend for community mobility & patient cohort [7]. The ICU demand projection can be predicted with help of hospital admission forecast which is the main factor for getting results. Individual risk profile is also important to predict the capacity of ICU beds needed.

A machine learning based exploration of COVID-19 mortality risk [8]. The main objective of this paper was to: predict the mortality risk from the admission of patients in the hospital checks the clinical data and investigate the possibility of predicting mortality outcome using non-invasive patient features, provide a direct comparison of mortality prediction powers between invasive and non-invasive patient features. The author used three machine learning models: Linear Support Vector Machine (LSVM), Neighbourhood Component Analysis (NCA), Recursive Feature Elimination SVM(SVM-RFE). Three machine learning models were developed using SVM framework with three inputs: Invasive, Non-invasive and their combination [9]. Invasive feature consists of laboratory results, Non-invasive features consist of patient clinical and demographic data, combined group consisted the combination of invasive and non-invasive features. After getting three process that represents the prediction performance provided by the non- invasive, joint and invasive. In the future the non -invasive model had a good result and the prediction was useful. Invasive shows good prediction performance for the near future.

To estimate the need for hospital resources using various strategies to reduce social mixing and analyse the capacity of health resources to meet the sudden outbreak of Covid-19 in future [10]. To get an insight into the Covid-19 progression the author proposed Susceptible-Exposed-Infectious and Recovered (SEIR) model and the model is further reimplemented according to the infection status and the severity of the patient into Susceptible (S), Exposed (E), Latency, Infected(I), Quarantined and Removed(R) and included the age structure of different groups. The main parameter is incubation time, symptomatic to recover or severe time, severe to recover or critical time, critical to recover or death time, latency time, probability of infection and test to positive ratio.

Role of Machine learning techniques are used to tackle the Covid-19 crisis [11]. The main objective of this study is to fight the Covid-19 crisis in the field of diagnosis, epidemiology and disease progression. In this study, the author used PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis). In this, there are four procedures: the first step is Identification, that is records identified through database search, then second step is Screening based on title and abstract, after that in the third step eligibility is checked and at last fourth step is inclusion. In this paper there are 3 parameters first one is [12] Computational Epidemiology: which focuses on the development that tries to solve the issues central to epidemiology. Second is Early Detection and diagnosis: an AI Application is used to detect and differentiate Covid-19 patients from general population. Third parameter is Disease Progression: predict the severity and disease progression. In this review, the author focused about providing insights on the prospects of AI on the 3 themes identified on Covid-19: CE, EDD & DP. Through CE they predicted the Covid-19 disease trajectory, Molecular analysis (drug discovery), facilitate Covid-19 response, through EDD we check the infections with the help of x-ray, computed tomography, lung ultrasound [13]. Through DP we predict the risk stratification and main focus on hospital resource management [14].

Using machine learning to predict ICU transfer in hospitalized Covid -19 patients. The main objective is to predict the Covid-19 patient required an intensive care. The author follows those steps first is to study cohort and features and then sampling strategy after that labelling, in this method labelling on the basis of positive label when patient was transferred to ICU, negative label when patient was transferred to ICU and negative label when patient was not transferred to ICU and then training, testing and cross-validation after that feature selection then model testing [15]. The author study cohort characteristics for each patient and study features and model hyper parameters then predict the performance of the model. The model gives the tool for risk quantification for ICU transfer within 24 hours. We develop a model for identifying patient in need of ICU transfer from daily routine data. The limitation is low sample size and most of the cases of Covid-19 were asymptomatic and the cases were not reported.

3. Discussion and Research Gap Identification

The detail discussion of our study and analysis is shown in tabular form as mentioned in Table 1. Many limitations and research gaps were identified by doing comparative study of research papers given in Table 1. In the first paper of the Table-1, limitations were that some danger cases are not reported, some demographical were not included and Hybrid SNN-NAR-NN model is not that efficient for long-term mortality rate prediction. In the second paper, the limitations were the dependability on data characteristic, no. of samples, and features interaction. In the third paper, the limitation was that the use of backdated framework.

Table 1: Comparative Study and Critical Analysis of presented Literature Survey

S. NO.	TITLE WITH FULL REFERENCE	OBJECTIVE OF PAPER	PROPOSED METHODOLOGY	DATASET	PARAMETERS	RESULT AND DISCUSSIONS	LIMITATIONS	FUTURE SCOPE
1.	Mortality Rate Prediction for India Using Statistical Neural Network Models https://www.frontiersin.org/articles/10.3389/fpubh.2020.00441/full	The main objective is to predict mortality rate for Covid-19 and estimate the future death cases in India due to pandemic.	RMSE value was found for the two datasets using 3 SNN models and was compared, if the RMSE value is lower it is the new predicted value otherwise error was found using NAR-NN time series forecasting model.	1.Time series of Covid-19 Death cases 2.Confirmed and death cases. https://www.kaggle.com/sudalairajkumar/novel-corona-virus-2019-dataset?select=time_series_covid_19_deaths.csv	A fixed architecture was taken for the hidden layer and out of that 10-15 no. of neurons were trained using Bayesian regularization.	Predicted curves are made for both standard and hybrid SNN. Death values are predicted for both D1 and D2 using PNN, RBFNN and GRNN.	1.The cases which are not reported. 2.Some Demographical were not included. 3. Hybrid SNN-NAR-NN model is not that efficient for long-term mortality rate prediction.	Recurrent Neural Network time series forecasting model will be used and other factors will be included.

2.	CPAS: The UK's National Machine Learning-Based Hospital Capacity Planning System for Covid-19 https://doi.org/10.1007/s10994-020-05921-4	The main objective is to plan for the hospital capacity and ICU beds capacity.	Aggregated trend forecaster first generates a forecast of daily hospital admissions and then generate the patient cohort then next individual risk predictor obtains the calibrated ICU admission risk on the nth day after hospital admission.	1.No. of patients hospitalized 2.intensive care national audit and research centre database. https://link.springer.com/article/10.1007/s10994-020-05921-4/figures/4	1.desired resolution 2.select hospital 3.trend for community mobility 4.patient cohort	Hospital admission forecast is the main factor for getting a results. Individual risk profiles is also important to predict the capacity of ICU beds needed.	Limitations are the dependability on: data characteristic, no. of samples, and features interaction.	In the future to focus on the temporal shift on feature distribution Auto ML will be used.
3.	A machine learning based exploration of COVID-19 mortality risk https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0252384#sec008	The main objective of this paper is to develop the mortality prediction model from patients first day of admission.	The author used three machine learning models: 1.Linear Support Vector Machine (LSVM) 2.Neighborhood Component Analysis (NCA) 3.Recursive Feature Elimination SVM(SVM-RFE)	Demographic, clinical features and mortality outcomes of patients collected from medical records. https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0252384.t002	1. Diagnosis criteria. 2.Patient severity classification criteria for non-serve and serve.	The early expirations are better predicted by the invasive features but can easily be exceled by non-invasive features.	This study was forwarded with a backdated framework.	In future, prognosis prediction software could be conceived on different platforms.
4.	Capacity need gap in hospital resources for varying mitigation and containment strategies in India in the face of Covid-19 pandemic https://www.sciencedirect.com/science/article/pii/S2468042720300415?via%3Dihub	Objective is to estimate the need for hospital resources using various strategies to reduce social mixing and analyse the capacity of health resources to meet the sudden outbreak of Covid-19 in future.	The author proposed Susceptible-Exposed-Infectious and Recovered (SEIR) model and this model is modified according to infection status into Susceptible(S), Exposed(E), Latency, Infected(I), Quarantined and Removed(R) and included the age structure of different groups.	Incubation period, as well as time from onset of COVID-19 symptoms to first medical visit, ICU admission, recovery and death of COVID-19. https://www.medrxiv.org/content/10.1101/2020.04.01.20050138v1	1.Incubation time. 2.symptomatic to recover or severe time, severe to recover or critical time, critical to recover or death time. 3. latency time 4.probability of infection 5.test to positive ratio	Lockdown is likely to push the flow in need for hospital resources by a month without suppressing the total number of cases significantly.	This model did not consider the potential staff shortages.	In future, it could be applied at more powdered level so that resources can be utilised at local level government system.
5.	Role of Machine learning techniques	The main objective of this study is to fight the	In this, there are four procedures: the first step is Identification, that is records	PubMed, Web of Science, and CINAHL	1.Computational Epidemiolog	Through CE they predicted the Covid-19 disease	1.Some studies could have been not	In the future the author is proposing

	used to tackle the Covid-19 crisis. https://medinform.jmir.org/2021/1/e23811/	Covid-19 crisis in the field of diagnosis, epidemiology and disease progression.	identified through database search, then second step is Screening based on title and abstract, after that in the third step eligibility is checked and at last fourth step is inclusion.	databases are collected.	y 2. is Early Detection and diagnosis 3. Disease Progression	trajectory, Through EDD they checked the infections with the help of x-ray, Through DP they predicted the risk stratification.	included. 2.Publications whose full text were not available are excluded.	to introduce another review of the future studies that are going to be progress.
6.	Using machine learning to predict ICU transfer in hospitalized Covid - 19 patients. https://www.mdpi.com/2077-0383/9/6/1668/htm	The main objective is to predict if the Covid-19 patient required intensive care.	RF model-derived class probabilities were used to predict ICU transfer within 24 h with a default threshold of ≥0.5. Predictions less than the default threshold were categorized as negative.	https://www.mdpi.com/2077-0383/9/6/1668/s1	1.Study cohort and features, sampling strategy 2. Labelling, training, testing and cross-validation 3. feature selection & model testing.	The RF-based tool can reliably be used for prioritizing COVID-19 patients not in the ICU but at risk for deterioration and requiring ICU transfer within 24 hours.	The limitation is low sample size and most of the cases of Covid-19 were asymptomatic and the cases were not reported.	In the future to improve the early identification of Covid-19 risk deterioration new machine learning models could be implemented.

In the fourth paper of Table 1, the limitation was that author's proposed model did not consider the potential staff shortages. In the fifth paper, the limitations were that some studies could have been not included publications and full text were not available or excluded. Finally, in the sixth paper, the limitation was the low sample size and due to this most of the cases of Covid-19 were asymptomatic and these cases were not reported.

4. Research Challenges

During the final analysis of all the research papers that we have read in context of our domain of study, we faced various challenges. First challenge was to find the most appropriate and nearest research papers of our domain because very less work has been done so far.

The next challenge was that there were many research papers which contained confusing data and incomplete model, so this was also a difficult challenge to filter out what we needed for analysis.

5. Conclusion

We studied different research papers that are relevant to our model and are useful for our domain to get conclusive remarks. In the first paper, we concluded that the predicted curves are made for both standard and hybrid SNN so that death values are predicted for both d1 and d2 using PNN, RBFNN and GRNN. In the second paper, we concluded that the ICU demand projection can be predicted with help of hospital admission forecast which is the main factor for getting results. Individual risk profile is also important to predict the capacity of ICU beds needed. In the third paper, we concluded that the early expirations are better predicted by the invasive features but can easily be exceled by non-invasive features. In the fourth paper, we concluded that the lockdown is likely to push the flow in need for hospital resources by a month without suppressing the total number of cases significantly. In the fifth paper, we concluded that through CE they predicted the Covid-19 disease trajectory, Through EDD they checked the infections with the help of X-ray, Through DP they predicted the risk stratification. And in the last paper we will concluded that the RF-based tool can reliably be used for prioritizing COVID-19 patients not in the ICU but at risk for deterioration and requiring ICU transfer within 24 hours.

6. Future Work

In the future, we suggest all the researchers to consider and use our comparative analysis because we have included all the advantages, disadvantages and objectives of more relevant research papers. In future, we can make best optimised method for hospital resource management to find the most appropriate solution for this new emerging problem. The first step that we are going to do is Risk Prediction since it is the main and foremost step to find the risk of the patient and then decide whether to shift him to ICU and give access to special resources like beds, oxygen supply etc. In future, we can manage the hospital resources effectively and decide which patient need resources firstly in comparison to others. With experimental validation, we can also model Hospital Resource Management accurately using some new algorithms of Deep Learning.

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