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Long-Term Survival Prediction After Liver Transplantation Using Convolutional Neural Networks

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***Abstract*—** Due to the technology innovations, a medical diagnosis has developed as an emerging area in the healthcare systems. Over the past decades, different reliable prediction models have been developed according to the survival analysis method with different degree of success. A survival of patient's after liver transplantation has been predicted by using Multi-Layer Perceptron Artificial Neural Network (MLP-ANN) model for better diagnosis. Conversely, patients undergoing liver transplantation may have a very poor diagnosis. Also, it depends on the proper selection of attributes and model. Hence in this article, an enhanced model is proposed for prediction of long-term survival of patient's after liver transplantation. Initially, data are collected and the Principal Component Analysis (PCA) is applied for dimensionality reduction which removes unnecessary attributes of liver patients. Then, the data is trained separately by using Convolutional Neural Network (CNN) model with the suitable selection of data attributes. Finally, the performance of the proposed model is analyzed and compared with the existing MLP-ANN model in terms of sensitivity, specificity and accuracy. The experimental results show that the proposed CNN model achieves high prediction accuracy in survival analysis after liver transplantation.

***Keywords*—**Liver transplantation, Survival prediction, MLP-ANN, Convolutional neural network, Principal component analysis.

I. INTRODUCTION

Liver transplantation or hepatic transplantation refers to the replacement of a diseased liver with the healthy liver from another individual. It is a diagnosis choice for end-stage liver disease and acute liver failure, though the availability of donor organs is a major limitation. It is a possible diagnosis for chronic conditions which cause irremediable and severe liver dysfunction [1]. The tremendous improvements in the liver transplantation throw light on the humans who are in need of survival. The accomplishment of liver transplantation surgery is analyzed by predicting the survival.

The surgical effects in liver transplantation are mainly depending on different factors such as infection severity, availability of donor organs, immunosuppression and forecasting the survival. In medicine, the medical experts get the judgment of an effect of liver transplantation according to the Model for End-Stage Liver Disease (MELD) score [2].
Different data mining algorithms have been proposed to support the healthcare systems which are used to predict the different diseases based on their symptoms [3]. Most of the prediction systems use ANN [4] to predict the diseases like brain hemorrhage, etc. Over the past decades, researchers conducted different prediction models of survival of patients after liver transplantation using a logistic regression model and ANN. They collected the data for the study from different hospitals, universities, etc.

Though using MELD score, patients undergoing liver transplantation surgery may still have very poor prediction due to the low survival and high recurrence rates related to the processes. Generally, the low survival rate occurs due to an improper selection of parameters and model. As a result, an effective and accurate ANN model was proposed [5] for the prediction of long-term survival of liver patients who undergo liver transplantation. In this model, a 10-fold cross validation was applied in the input dataset and the data was trained by using the MLP ANN model with the proper selection of data attributes.

Hence in this article, the urvival of patients after liver transplantation is predicted by using Convolutional Neural Network (CNN). Initially, the data are collected and PCA is applied to reduce the dimensionality of a large dataset with ranking. Then, CNN is used to classification process which analyses the survival rate of liver transplantation and also survival probability of liver patients. Based on this proposed CNN-based survival data modeling, the prediction accuracy is improved efficiently with the appropriate selection of dataset and model.

The rest of the article is structured as follows: Section II presents the previous researches related to the prediction of a patient's survival after liver transplantation. Section III explains the proposed methodology. Section IV illustrates the performance efficiency of the proposed method compared to the existing method. Section V concludes the article and suggests the future scope.

II. RELATED WORK

Patient survival after liver transplantation [6] was predicted by using evolutionary multi-objective ANN. The main aim of this prediction was determining the patient's survival based on the characteristics of the donor, recipient and transplant organ. The issue of organ allocation was addressed based on the Memetic Pareto Evolutionary Non-dominated Sorting Genetic Algorithm 2 (MPENSGA2) which was used for training the radial basis function of ANN. Here, the ANN model was obtained from the Pareto fronts which were used for developing the rule-based system. The performance of this method was analyzed based on the data of liver transplants collected by Spanish hospitals.

Graft survival prediction after liver transplantation was proposed by using ANN models [7-9]. The major aim of this system was developing a model for short-term survival prediction of liver patients. In this study, the data was collected from the United Network for Organ Sharing (UNOS) transplant registry. The entire data was split into training and testing according to the 10-fold cross-validation. Short-term survival after liver transplantation [10] was predicted based on the eight score systems. In this method, eight score systems namely MELD, uMELD, MELD-Na, iMELD, UKELD, MELD-AS, CTP and mCTP were utilized during predicting the post-transplant mortality. Moreover, a large cohort of patients from the China Liver Transplant Registry (CLTR) database was used to analyze the efficiency of pre-transplant MELD and the other scoring systems.

Computer-based prognosis model [11] was proposed for prolonged survival prediction based on the dimensionality reduction and validation of attributes. Initially, data were collected from the UNOS registry and filtered physically. Then, the PCA was applied to reduce the dimensionality of the data. After that, the attributes were ranked as strong or relevant attributes. Finally, association rule mining techniques such as Apriori, Treap mining and Tertius algorithms were used to predict the relationship between the selected attributes. Moreover, the MLP model was constructed to predict the long-term survival of patients after liver transplantation. Survival of kidney transplant recipients was predicted [12] by using two intelligent techniques such as data mining and logistic regression. The main aim of this study was developing a model to predict survival of kidney transplant patients. However, the time complexity of those models was high for determining the required attribute values.

III. PROPOSED METHODOLOGY

In this section, the proposed CNN model for prediction of long-term survival of patient's after liver transplantation is explained in brief. Initially, the dataset is gathered from the UNOS database that consists of pre-transplant and post-transplant multi-organ data. A total of 65535 records with 389 attributes from October 1, 1994, to January 15, 2018, are collected. Among 389 attributes of patients, 256 attributes are attributes of liver patients concerning liver transplantation. The attributes of donors, recipients and transplantation are also included. In addition, the dataset consists of both male and female and pediatric liver patient records.

In each dataset, 59 attributes are removed manually and PCA is applied among the remaining 256 attributes for dimensionality reduction. Based on the ranking, only 27 relevant attributes are obtained to achieve long-term survival with high accuracy. After that, the 27 input attributes are given to the CNN model to train the clinical attributes of a patient related to the liver transplantation.

A. Convolutional Neural Network Classifier

Some of the input attributes of patients and their description are given in Table 1. The CNN algorithm is multilayer perceptron and has more layers such as an input layer, a convolution layer, a sample/pooling layer and an output layer. It has two major phases such as convolution and sampling phase.

Table 1. Some Examples of Input Parameters, Characteristics and Their Composite Variables

Input Attributes	Description	Composite Variables
AGE_DON	Donor age in years	Donor
CLIN_INFECT_DON	Decreased donor-clinical infection (Y,N)	
CREAT-DON	Decreased donor-terminal lab creatinine	
DIABETES_DON	Decreased donor-history of diabetes (Y,N)	
DON_TY	Donor type (Decreased, Living)	
GENDER_DON	Donor	

	gender	
FINAL_ALBUMIN	Most recent recipient Albumin	Recipient
FINAL_MELD_OR_PELD	Most recent recipients use MELD/PELD	
FINAL_MELD_PELD_LAB_SCORE	Most recent recipient MELD/PELD lab score	
FINAL_SERUM_CREAT	Most recent recipient Serum Creatinine	
FINAL_SERUM_SODIUM	Most recent recipient Serum Sodium	
GENDER	Recipient gender	
INIT_AGE	Age in years	
NUM_PREV_TX	Number of previous transplants	Transplantation
TXLIV	Type of liver (W,S)	

In CNN, the input layer represents each attribute for predicting the survival rate and survival probability. For the units in each layer up to the sample layer, the dot product is computed between the input vector and input attributes, to which a bias value is added. The weighted sum for unit i is denoted as b_i which is passed through the sigmoid squashing function for producing the state of unit i and denoted by x_i:

$$x_i = f(b_i) \quad (1)$$

The squashing function is defined as the scaled hyperbolic tangent and given as:

$$f(a) = A\ tanh(S_a) \quad (2)$$

Where A is the amplitude of the function and S determines its slope at the origin. Then, the output layer is composed of Euclidean Radial Basis Function (RBF) and output of each RBF unit y_i is computed as follows:

$$y_i = \sum_j \left(x_j - \theta_{ij}\right)^2 \quad (3)$$

Each output RBF unit measures the Euclidean distance between its input vector and parameter vector. The output of certain RBF can be interpreted as a penalty term measuring the fit between the input and a model of the class associated with the RBF. Thus, the input parameters are automatically learned to predict the survival of patient's after liver transplantation.

IV. Results and Discussion

In this section, the performance effectiveness of the proposed model is analyzed and compared with the existing model by using MATLAB 2018a. The comparison is made in terms of performance measures such as specificity and accuracy. A new dataset of 3055 records of liver patients is generated according to the survival year after liver transplantation. The input dataset contains liver transplantation date, retransplantation date and data of follow-up. According to this, 421 records are extracted with the follow up information.

A. *Specificity*

It is defined as the ratio of correctly predicted outcomes at true negative values and is computed as,

$$Specificity = \frac{True\ Negative\ (TN)}{TN + False\ Positive\ (FP)}$$

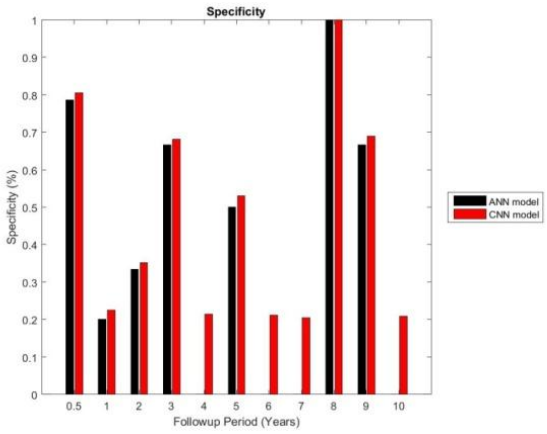

Figure 1. Comparison of Specificity

Figure 1 shows the comparison of specificity for proposed CNN model and existing ANN model in the prediction of survival of patients after liver transplantation. From this analysis, it is observed that the proposed CNN-based prediction model achieves better specificity than the ANN-based prediction model.

B. *Accuracy*

It is defined as the ratio of true positives and true negatives to the sum amount of cases examined. It is measured as,

$$Acc = \frac{TP + TN}{TP + TN + FP + FN}$$

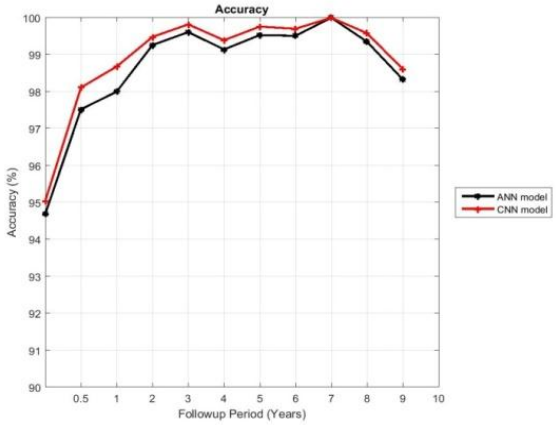

Figure 2. Comparison of Accuracy

Figure 2 shows the comparison of accuracy for the proposed CNN model and existing ANN model in the prediction of survival of patients after liver transplantation. From this analysis, it is observed that the proposed CNN-based prediction model achieves high accuracy than the ANN-based prediction model.

V. CONCLUSION AND FUTURE SCOPE

In this article, a CNN model is proposed for prediction of long-term survival of patient's who undergo liver transplantation. In this model, the dataset is collected with different attributes of a patient related to the liver transplantation. The most relevant attributes are selected by achieving dimensionality reduction using PCA. Then, the dataset with the proper attributes is trained based on the CNN classifier. Thus, the proposed prediction model helps to analyze the survival rate of liver patient's effectively. Finally, the experimental results prove that the proposed CNN-based prediction model outperforms than the MLP-ANN model in terms of prediction accuracy and specificity. As a part of future work, parameter selection could be improved by using optimization algorithms to determine the most optimal parameters efficiently.

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Authors Profile

Mubeena achieved the MCA degree from MES Engineering College, Calicut University, India in the year of 2010 and M.Phil degree in Computer Science from Bharathiyar University, India in the year of 2017 respectively. Currently, she is a guest lecturer of Computer Science, Farook College, affiliated by Calicut University. She has a total experience of over 3 years. She has published a paper on Data mining. Her area of interest is data mining and image processing.

