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Managing Hospital Emergency Departments in Traffic-Intensive Area

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ABSTRACT

Emergency department crowding has been one of the major issues in healthcare systems. One solution to this is the prediction of admissions in the emergency department and allocating resources needed for the admitted patients. In this paper, predictive model is developed using neural networks for predicting the admissions. An expert selection algorithm is developed to assign the department/doctors for the admitted patients. After getting the references the availability of resources needed for the admission is done and the available resources are allocated. Neural networks are used to build the predictive model because of its ability to develop an artificial system which can do intelligent tasks similar to human brain and its ability to represent both linear and non-linear relationships. The system developed effectively reduced crowding in the emergency department by predicting the admissions and does the needful for the admissions. It also helped effectively manage the admissions from the emergency department when there was a crowded scenario.

KEYWORDS: emergency department ; crowding; neural network.

1. INTRODUCTION

Crowding within Emergency Departments (EDs) can have adverse effects for patients and staffs such as increased wait time, cross infections among patients, reduced staff availability, increased mortality, and cancellation of elective procedures. There are many causes of high traffic in EDs depending on the context such as increased patients, inappropriate attendances, a lack of alternative treatment options and lack of inpatient beds, ED staffing shortages, and unavailability of other local ED departments. The most significant of these causes is the inability to transfer patients to particular departments, making it critical for hospitals to manage patient flow and understand the patient's requirements. EDs therefore needs a system to manage the crowding in such scenarios. One mechanism to reduce ED crowding and improve patient flow is the use of deep learning techniques to identify patients at high risk of admission that would help to improve patient satisfaction by providing the patient with advance notice that admission is likely to happen.

Patients attending the ED generally go through several stages. They can arrive through main reception area or in an ambulance. The patient's details are collected on the main ED administration system, before the patient is either admitted or proceeds to the waiting area. The patient then waits for a target time or less before examined by a specialist nurse. Taking decision on prioritising patients based on the severity of their condition and to identify patients who are likely to deteriorate if not seen urgently and those who can safely wait to be seen . This is an important stage in the patient journey to ensure the best use of resources, patient satisfaction, and safety. Once done the assessment by a clinician, who will make a recommendation on the best course of action, which could include treatment, admission, follow up at an outpatient clinic or discharge. If there is an admission then which department to prioritise, available resources for the patients are the important decisions to be taken. These decisions create a hurdle in the emergency department. This will in turn create a heavy traffic scenario in the ED.

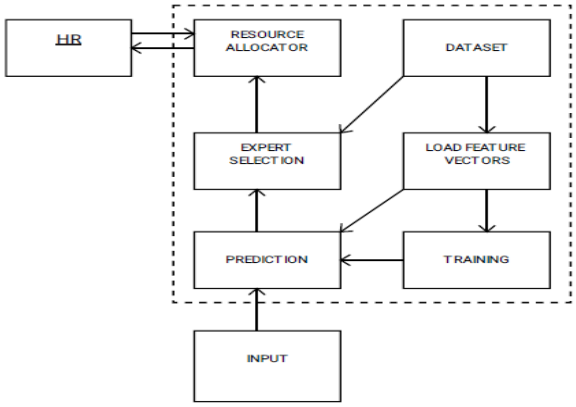

Figure 1 Overview of the system

This paper focuses on the use of neural networks to develop models to predict hospital admissions from the emergency department. Then an algorithm for expert selection for the predicted admission and allocate available resources for the admitted patients is developed. Figure 1 gives an overview of the system developed. Routine recoding of data on hospital administrative systems takes place at each stage of this process, providing an opportunity to use machine learning to predict whether there is an admission. This paper draws on this data to achieve two objectives. The first is to create a model that accurately predicts admission to hospital from the ED department, second to provide experts using an expert selection algorithm. After the prediction available resources are allocated for the patients.

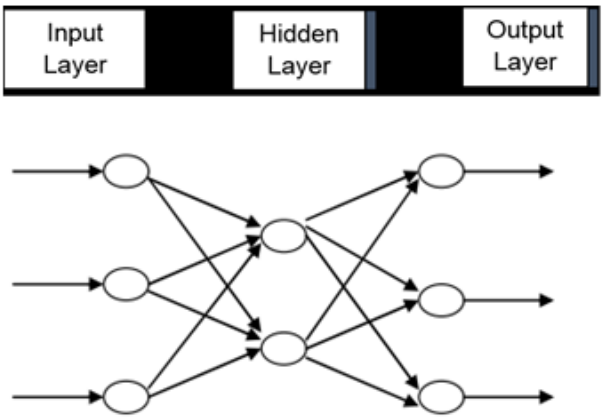

Figure 2 Simple neural network

Artificial Neural Network (ANN) uses the processing similar to develop algorithms that can be used to model complex patterns and predictions. Figure 2 is an example of simple neural network. The network architecture has an input layer, hidden layer (there can be more than 1) and the output layer. The hidden layer can be seen as a “distillation layer” that distills some of the important patterns from the inputs and passes it onto the next layer to see. It makes the network faster and efficient by identifying only the important information from the inputs leaving out the redundant information. The activation function serves two notable purposes, it captures non-linear relationship between the inputs and helps convert the input into a more useful output. Given are some advantages of using neural networks

- The ability to learn and model non-linear and complex relationships, which is really important because in real-life, many of the relationships between inputs and outputs are non-linear as well as complex.
- Neural networks can generalize i.e. after learning from the initial inputs and their relationships, it can infer unseen relationships on unseen data as well.
- Does not impose any restrictions on the input variables.

- Can better model data with high volatility and non-constant variance, given its ability to learn hidden relationships in the data without imposing any fixed relationships in the data..

2. METHODS

The method for this study involved data mining tasks such as Data extraction, Data cleansing and feature Engineering, Data visualisation and descriptive statistics, Data was split into training (80%) and test sets (20%).Model tuning was done using the training set and 10-fold cross validation repeated 5 times. Predicting admissions was based on the test data set and the evaluation of model performance based on predictions made on the test data. These steps help to ensure the models are optimal.

Neural networks are used to develop models to predict hospital admissions from the emergency department. Then an algorithm for expert selection for the predicted admission and allocate available resources for the admitted patients is developed. The process is done in three stages preprocessing, modelling a neural network and an expert selection algorithm

A. Preprocessing of dataset

We used the Medical Information MIMIC-III publicly available dataset, which includes all patients admitted to an ICU at the Beth Israel Deaconess Medical Centre from 2001 to 2012.Deep learning models consistently perform best among all the other approaches especially when the `raw' clinical time series data is used as input features to the model.

The MIMIC-III dataset is in a CSV format that was converted to vector form. The patients were categorised into three as urgent, emergency and elective. The first two categories were labelled as admitted label and the last one as not admitted.

B. Modelling neural network

The neural network is modeled using MIMIC-III dataset.The following are the steps for modeling the neural network.

- Select a candidate set of features.
- Define number of hidden layers and computational units in each layer.
- Load dataset
- Obtain training and test data sets based on candidate features using k-fold cross validation technique.
- For each such pair, train one distinct model using training dataset and measure its performance against test data set. Compare the models and pick the one with best performance.
- If result of the best performance model is satisfactory then stop.
- Otherwise, if improvement is observed, go to step 5 to increase complexity of the model with more computational units and/or layers.

C. Expert selection algorithm

An expert selection algorithm was developed to prioritize the admitted patients to the departments. This was done using modifying KNN algorithm as shown in Figure 3 shows the expert selection algorithm.

```
NearestLabels(X, Y, x, t)
 X: training data, Y: class labels of X, x:unknown sample,
t: threshold
1. For I = 1 to m do
1. a. D: =Compute distance d (Xi, x)
End for
2. Compute set Ds containing indices for the k smallest
distance d (Xi, x)
3. Update DS: =dsi where dsi less than t
4. Return majority label for Yi (where i belongs to Ds)
```

Figure 3 An expert selection algorithm

3. Results and Discussions

A. Neural networks

Neural network was trained using the MIMIC-III dataset. The training process was done using sigmoid and ReLU activation function and model was developed for predicting admissions. Single layer neural network gave a better performances compared to multiple layer neural network for the MIMIC-III dataset.

B. Activation functions

The Sigmoid activation function is also called logistic function. The Sigmoid is a non-linear AF used mostly in feed forward neural networks. It is a bounded differentiable real function, defined for real input values, with positive derivatives everywhere and some degree of smoothness. The sigmoid function is used in the output layer to predict the output. the sigmoid is used in the output layer since it is a binary classification.

Softmax function was also used in the output layer to predict output but sigmoid gave better performance. Table I gives the performance of the system while using the different activation functions.

Table II Activation function performance comparison

Activation function	*Accuracy (%)*
Sigmoid function	95.5
Softmax function	90.3

The rectified linear unit (ReLU) offers the better performance and generalization in deep learning. The ReLU represents a nearly linear function and therefore preserves the properties of linear models that made them easy to optimize, with gradient-descent methods.

The ReLU activation function performs a threshold operation to each input element where values less than zero are set to zero. The hidden layer uses ReLU activation function.

C. Other machine learning techniques

Three machine learning approaches such as logistic regression, decision tree and GBM were also used to predict the admission with the same dataset. All the three gave almost similar performances. Out of the three and neural networks, single layer neural network gave a better performance. Table

III gives the comparison performance of our dataset with the neural network versus other machine learning techniques

Table IV comparison with other machine learning techniques

SI.No	**Performance comparison**		
	Predictive models	***Accuracy (%)***	***Sensitivity***
1.	Logistic regrssion	79.94	.5357
2.	Decision tree	80.06	.5349
3.	GBM	80.31	.5379
4.	Neural networks	83.01	.5332

4. CONCLUSION

This study involves development and analysis of machine learning models for predicting hospital admissions in the emergency department. An expert selection algorithm was developed by modifying KNN algorithm to find the department and selection of experts. The system performed well in a heavy traffic scenario in the emergency department that efficiently helped management of emergency department in crowded scenarios. Thus helps in proper clustering of patients in heavily crowded emergency department. Clustering the patients helped in many ways such as avoiding cross infection among the patients, allocating resources among the patients. As a long term benefit the system developed would help for the planning and management of hospitals.

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