Proceedings of the 2023 Design of Medical Devices Conference
DMD2023
April 17-19, 2023, Minneapolis, MN, USA

DMD2023-1597

ITINERARY PREDICTIVE ANALYTICS: AI BASED SOFTWARE AS A MEDICAL DEVICE TO PREDICT PATIENTS' FIRST VISIT ITINERARY FOR HEALTHCARE ADMINISTRATION

Shivam Damani
Department of Medicine, Mayo Clinic
Rochester, MN, USA

Keerthy Gopalakrishnan
Department of Medicine, Mayo Clinic, Rochester, MN, USA

Keirthana Aedma
Department of Medicine, Mayo Clinic, Rochester, MN, USA

Pratyusha Muddaloor
Department of Medicine, Mayo Clinic, Rochester, MN, USA

Vinay Chandrasekhara
Division of Gastroenterology, Mayo Clinic, Rochester, MN, USA

Alexander J. Ryu
Department of Medicine, Mayo Clinic
Rochester, MN

Christopher A. Aakre
Department of Medicine, Mayo Clinic
Rochester, MN, USA

Shivaram P. Arunachalam
Department of Medicine, Mayo Clinic, Rochester, MN
USA

ABSTRACT

Majority of hospitals still utilize manual methods for patient scheduling and predicting future appointments, resulting in longer wait times, hospital burnout and inadequate use of resources. A variety of avenues have been explored, including priority patient routing, tele-health, neural networks for improving ER efficiency, predicting no-shows, consultation duration variations, and optimizing operating room utilization. Addressing this issue, a study was conducted using 700 pre-visit notes of pancreatic patients to determine the requirement of endoscopic or biliary procedure. Through natural language processing and traditional or transfer learning algorithms, data could directly be sent to EPIC for nurses to assess in further decision making. Performance of the models was above average with the transfer learning method outperforming the traditional method. Although limited by less dataset and fewer circumstances to test the models on, the results exposed potential for future development with the possibility of patients reporting their chief concerns, in turn analyzed by algorithms, ultimately creating a smooth and effective patient itinerary.

Keywords— Itinerary Prediction, Patient Scheduling, Patient Visits, Natural Language Processing, Deep Learning.

1. INTRODUCTION

Delayed access to healthcare services can lead to poor health outcomes due to delays in diagnosis and treatment [1]. There is very little research on patient wait time in various healthcare facilities. Scheduling a physician's appointment or a procedure is an unpleasant experience for patients. However, it is still a manual process in most healthcare facilities. Each healthcare setup has a unique scheduling system that creates different challenges in managing appointments. Various factors affect the appointment systems, including the efficiency of the scheduling staff, patient and physician preferences, and available information technology [2]. As a result, patient wait times increase, and patients with long wait times tend to miss long-scheduled appointments leading to overwhelming emergency admissions [3,4].

A systematic review of the advanced access scheduling system by Rose KD et.al found that despite the reduction in wait times using advanced access, patients were not satisfied with the scheduling system or overall care [5]. A study by Turkcan A et al. suggests potential mechanisms for improving the scheduling process; one is the application of telehealth and artificial intelligence. They created an agent-based simulation to design the patient workflow and to determine the best patient scheduling method [6]. Munavalli JR et. al. proposed a patient scheduling model that predicted a pathway from entry to exit using prior information. The study incorporated information from all clinic departments to determine and optimize the pathway [7]. Another study proposed an AI model using a Temporal Convolutional Neural Network (TCNN) using patient's medical records to analyze the possibility of a patient requiring access to one or more facilities during different periods [8].

In addition, the healthcare industry generates enormous amounts of data every day that can be extracted to develop machine learning models for patient scheduling and itinerary prediction, which also helps overall well-being and responsive healthcare.[9] With this background, we attempted to solve the patient scheduling problem at destination medical centers using patient pre-visit text data to improve pre-visit itinerary planning by leveraging AI and natural language processing (NLP) to reduce administrative staff time and thus increasing the efficiency of the healthcare system. Given this motivation, our study focused on predicting Biliary and Endoscopic procedures in a pancreas clinic from pre-visit text notes using AI as a potential tool for software as a medical device (SaMD) for health care administration services.

2. MATERIALS AND METHODS

A. Data Description

Our study examined the pre-visit notes made by nurses at the pancreas clinic. An initial roadmap was developed by the physicians by using these notes, which contained personal details about the patient, such as age and sex, as well as disease specific information such as history, current symptoms, indications, prior imaging records, prior pancreatic procedures, and alkaline phosphatase, bilirubin, creatinine, amylase, lipase, Ca 19-9 and GFR levels. These labels were extracted and used as a starting point for our study. We retrospectively evaluated 700 pre-visit notes dating from October 8, 2019, to September 16, 2021, at the pancreas clinic. The target variables were the requirement of an endoscopic procedure(proc_eus) or a biliary procedure (proc_bil), both of which are dependant variables, and their values are calculated as shown below.

1. Endoscopic procedures: True if the patient required either a EUS or ERCP.

2. Biliary procedures: True if the patient required either EUS, ERCP, EGD, or COL.

B. Natural language Processing

Our study ultimately boils down to a text classification problem, an NLP problem which aims at assigning tags to text blocks. Machine learning algorithms learn inherent associations between text and their labels using prelabeled examples as training data. For this, we use classical and neural approaches. The classical models follow a two-step procedure for prediction. In the first step, hand-crafted features (bag of words) are extracted from text and then in the second step a classifier makes predictions based on those features. Commonly used classification algorithms include Naïve Bayes, support vector classifiers (SVC) and random forests. However, the classical approach has many limitations such as dependance on the handcrafted features, which requires hefty feature engineering and analysis for performance. Additionally, the dependence on domain knowledge for designing features makes it difficult to generalize this method to new tasks. Hence, this model cannot take full advantage of large amounts of training data because of the pre-defined nature of its features.

In our study, we tried to compare how the traditional models and the BERT inspired transfer learning impacted the itinerary and scheduling process by building a multi-label classification model. The pre-visit notes underwent preprocessing steps like tokenization, lemmatization, stop word elimination, etc. Around 700 notes were divided into an 80-10-10 train-validate-test split. These notes were used to predict the requirement of an endoscopic procedure (EUS or ERCP) and a biliary procedure (EUS, ERCP, EGD, or COL). Various machine learning models such as SVC, KNN, random forest, decision trees, Naïve Bayes methods and deep learning models were developed and compared.

3. RESULTS AND DISCUSSION

Table 1 summaries these results for accuracy, recall, precision and F1 scores for SVC, KNN, random forest, decision trees, Naïve Bayes methods and deep learning model performances. As seen from the Table, the deep learning model performed the best compared to the other models. Given that our model was trained on a very limited dataset, the performance metrics generated were above average. Hence, this is an indication that with the inclusion of additional data to the current training set, the model has a vast scope for improvement in its performance and thus have a greater impact on the prediction capabilities of itineraries within the pancreas clinic.

A deeper look at the results revealed that the attention based deep learning model outperformed the traditional model. However, it did not significantly improve the metrics like accuracy, precision, recall and f1 scores. Hence, it is recommended that future studies use the deep learning-based text classification algorithms in deployment. Fig 1. Shows he cyclic approach to optimize the model performance for clinical utility.

This model and pipeline served as a steppingstone towards automated patient itinerary building and appointment scheduling. It is also possible to adapt this workflow to the other clinics by creating a similar text field to summarize the patient's history, indications and symptoms and then scale the model to different clinics therefore has a potential to become a software as a medical device for healthcare administration services.

TABLE I. SUMMARY OF MODEL PERFORMANCE

	Accuracy	Recall	Precision	F1 score
SVC	**0.58**	**0.52**	**0.48**	**0.50**
KNN	**0.53**	**0.46**	**0.46**	**0.46**
Random Forest	**0.59**	**0.54**	**0.45**	**0.49**
Decision Trees	**0.56**	**0.49**	**0.48**	**0.48**
Naïve Bayes	**0.56**	**0.49**	**0.62**	**0.54**
Deep Learning	**0.76**	**0.79**	**0.77**	**0.78**

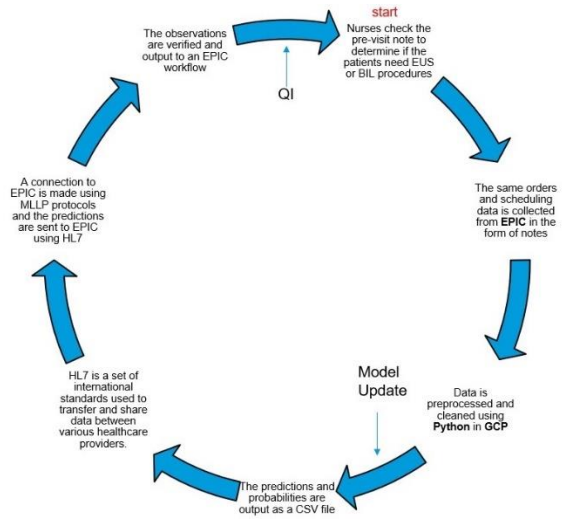

Fig 1: Figure illustrating the cyclic workflow for the model implementation in clinical setting

The outputs of the model are sent through a HL7 message, populated into a flowsheet, which is directly uploaded to EPIC, where the nurses who are scheduling the appointments can see the results generated by the model, which subsequently can assist in the decision-making process. However, the study has the following limitations. First, the dataset was small, with an order in the thousands. Second, the model was only implemented to detect two procedures. Third, the subjective nature of the text data hurt the performance at a low dataset size. In future work, we will improve our system by using larger volumes of data and include more procedures.

4. CONCLUSION

In this study, traditional and transfer learning methods were applied to perform a text prediction on patients visiting the pancreas clinic at Mayo Clinic. The results indicate the potential of predicting patients first visit itinerary to optimize patient scheduling and procedure orders using an AI based software as a medical device that can enhance health care administrative services.

REFERENCES

[1] W. Kenagy, "Service Quality in Health Care," JAMA, vol. 281, no. 7, p. 661, Feb. 1999, doi: 10.1001/jama.281.7.661.

[2] Gupta and B. Denton, "Appointment scheduling in health care: Challenges and opportunities," IIE Transactions, vol. 40, no. 9, pp. 800–819, Jul. 2008, doi: 10.1080/07408170802165880.

[3] George A, Rubin G. Non-attendance in general practice: a systematic review and its implications for access to primary health care. Fam Pract. 2003 Apr;20(2):178-84. doi: 10.1093/fampra/20.2.178. PMID: 12651793.

[4] R. Chong, K. T. Tsai, L. L. Lee, S. G. Foo, and P. C. Chang, "Artificial Intelligence Predictive Analytics in the Management of Outpatient MRI Appointment No-Shows," American Journal of Roentgenology, vol. 215, no. 5, pp. 1155

[5] Rose KD, Ross JS, Horwitz LI. Advanced access scheduling outcomes: a systematic review. Arch Intern Med. 2011 Jul 11;171(13):1150-9. doi: 10.1001/archinternmed.2011.168. Epub 2011 Apr 25. PMID: 21518935; PMCID: PMC3154021.

[6] Turkan, "Patient-centered appointment scheduling using agent-based simulation," AMIA .. Annual Symposium proceedings / AMIA Symposium. AMIA Symposium, vol. 2014, pp. 1125–1133, Nov. 2014.

[7] R. Munavalli, S. V. Rao, A. Srinivasan, and G. van Merode, "Integral patient scheduling in outpatient clinics under demand uncertainty to minimize patient waiting times," Health Informatics Journal, p. 146045821983204, Mar. 2019, doi: 10.1177/1460458219832044.

[8] Piccialli, S. Cuomo, D. Crisci, E. Prezioso, and G. Mei, "A deep learning approach for facility patient attendance prediction based on medical booking data," Scientific Reports, vol. 10, no. 1, p. 14623, Sep. 2020, doi: 10.1038/s41598-020-71613-7.

[9] Nelson A, Herron D, Rees G, Nachev P. Predicting scheduled hospital attendance with artificial intelligence. NPJ Digit Med. 2019 Apr 12;2:26. doi: 10.1038/s41746-019-0103-3. PMID: 31304373; PMCID: PMC6550247.