World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:17, No:05, 2023

Interpretable Deep Learning Models for Medical Condition Identification

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Abstract : Accurate prediction of a medical condition with straight clinical evidence is a long-sought topic in the medical management and health insurance field. Although great progress has been made with machine learning algorithms, the medical community is still, to a certain degree, suspicious about the model's accuracy and interpretability. This paper presents an innovative hierarchical attention deep learning model to achieve good prediction and clear interpretability that can be easily understood by medical professionals. This deep learning model uses a hierarchical attention structure that matches naturally with the medical history data structure and reflects the member's encounter (date of service) sequence. The model attention structure consists of 3 levels: (1) attention on the medical code types (diagnosis codes, procedure codes, lab test results, and prescription drugs), (2) attention on the sequential medical encounters within a type, (3) attention on the medical codes within an encounter and type. This model is applied to predict the occurrence of stage 3 chronic kidney disease (CKD3), using three years' medical history of Medicare Advantage (MA) members from a top health insurance company. The model takes members' medical events, both claims and electronic medical record (EMR) data, as input, makes a prediction of CKD3 and calculates the contribution from individual events to the predicted outcome. The model outcome can be easily explained with the clinical evidence identified by the model algorithm. Here are examples: Member A had 36 medical encounters in the past three years: multiple office visits, lab tests and medications. The model predicts member A has a high risk of CKD3 with the following well-contributed clinical events - multiple high 'Creatinine in Serum or Plasma' tests and multiple low kidneys functioning 'Glomerular filtration rate' tests. Among the abnormal lab tests, more recent results contributed more to the prediction. The model also indicates regular office visits, no abnormal findings of medical examinations, and taking proper medications decreased the CKD3 risk. Member B had 104 medical encounters in the past 3 years and was predicted to have a low risk of CKD3, because the model didn't identify diagnoses, procedures, or medications related to kidney disease, and many lab test results, including 'Glomerular filtration rate' were within the normal range. The model accurately predicts members A and B and provides interpretable clinical evidence that is validated by clinicians. Without extra effort, the interpretation is generated directly from the model and presented together with the occurrence date. Our model uses the medical data in its most raw format without any further data aggregation, transformation, or mapping. This greatly simplifies the data preparation process, mitigates the chance for error and eliminates post-modeling work needed for traditional model explanation. To our knowledge, this is the first paper on an interpretable deep-learning model using a 3-level attention structure, sourcing both EMR and claim data, including all 4 types of medical data, on the entire Medicare population of a big insurance company, and more importantly, directly generating model interpretation to support user decision. In the future, we plan to enrich the model input by adding patients' demographics and information from free-texted physician notes.

Keywords : deep learning, interpretability, attention, big data, medical conditions
Conference Title : ICMLHM 2023 : International Conference on Machine Learning for Healthcare and Medicine
Conference Location : London, United Kingdom
Conference Dates : May 15-16, 2023