

Prediction of Patient Outcomes after Renal Replacement Therapy (RRT) in the ICU

Harry Freitas Da Cruz
Hasso Plattner Institute (HPI)
Enterprise Platform and Integration Concepts
Potsdam, Germany
Email: Harry.FreitasDaCruz@hpi.de

Siegfried Horschig
Hasso Plattner Institute (HPI)
Enterprise Platform and Integration Concepts
Potsdam, Germany
Email: siegfried.horschig@student.hpi.de

Abstract—In order to compensate impairments of the renal system in the human body, artificial methods in the form of renal replacement therapy (RRT), called dialysis, have to be introduced. Many parameters of the dialysis can be adjusted and the outcome of the procedure may change with different patient characteristics. In this paper, we introduce a clinical decision support system to predict the effect of a given dialysis on a patient while in the intensive care unit (ICU).

For this purpose, we employ two kinds of machine learning models: Bayesian Rule Lists (BRL) and Deep Neural Networks (DNN). Although the DNN may provide better accuracy, its decision making is not easily interpretable for humans. For this reason, we use mimic learning as a method to make the DNN interpretable.

Results show us that the DNN outperforms our BRL classifier as expected, but by a rather small margin. For the mimic learning process, we used a bayesian ridge regression model. Even though the regression model performs worse when training as a mimic model as opposed to directly on the data, it provides some insight into the inner workings of the DNN.

1. Introduction

The renal system in the human body has the purpose to eliminate wastes from the body and control levels of certain substances in the blood. If this system is impaired, for example due to Acute Kidney Injury (AKI), artificial methods in the form of Renal Replacement Therapy (RRT) have to be introduced, more commonly known under the term of dialysis.

There are different options for dialysis available. One example is the hemodialysis, where the patient's blood is pumped through a dialyzer, inside of which is a liquid called dialysate. This liquid's composition determines which substances should be filtered out of the blood. The dialyzer separates the blood and the dialysate through a partially permeable membrane, allowing for the filtering of the blood through osmosis. Another example for the dialysis is the peritoneal dialysis, which uses the peritoneal cavity inside the patient as a container for the dialysate.

The dialysis outcomes are highly dependent on both the patients characteristics and the parameters as well as the type of the dialysis. So, usually, patients undergoing the peritoneal dialysis experience lesser health issues related to the dialysis than those undergoing hemodialysis, as there is less pressure on the circulatory system. On the other hand, the hemodialysis is more efficient in such a way that it needs less time for the same amount of filtration.

Especially the hemodialysis is a costly process which needs specialized equipment and therefore has many parameters to be tuned. These include, but are not limited to the duration of the process, the filtration rate and flow rates of the blood and dialysate. We want to introduce a machine learning model that, based on those parameters as input, allows to make a prediction for the health of the patient after the procedure.

Aside from usual criteria like accuracy or recall, when employing a machine learning model in the medical context one especially important factor is the interpretability of the model. This is due to the fact that the doctors want to make decisions based on those predictions and take full responsibility for the consequences, so they have to validate the decision making process. Oftentimes, models just show correlations between various parameters, and those correlations have to be manually checked for causal relations. Additionally, the European Union introduced regulations (taking effect 2018) that give consumers in any sector a "right to explanation". Essentially, this means that in any decision making process that is done by machines, be it a credit application or a diagnosis, the individual has the right to access meaningful information about the logic involved.

This way, we can roughly separate machine learning algorithms in two categories: interpretable and non-interpretable. One example for interpretable models are Bayesian Rule Lists (BRL). By presenting itself as IF-THEN-ELSE lists, it is easy for humans to comprehend both the decision making and the individual influence of each parameter on the outcome.

Deep Neural Networks (DNN) on the other hand are

non-interpretable, because the weights of the nodes in the hidden layers is everything they expose to the outside. Due to the fact that different loss and activation functions take effect when updating those weights, the abstraction to the original input data is just too large for a human to grasp. For this reason, we want to make non-interpretable models interpretable, giving some insight into their inner workings and decision making.

The main purpose of this paper is to develop a clinical decision support system to determine patient-specific outcomes after RRT in the ICU and evaluate the interpretability of different models used in this process. We employ two different models, BRL as the interpretable one and DNN as the non-interpretable one. Afterwards, we show performance comparison of both those models and try to give some insight into the decision-making process of the DNN using mimic learning.

2. Related Work

In the field of prediction concerning the renal system, a lot of work has already been done. In [1] mortality of patients after RRT in the ICU was observed and set in relation to the method of dialysis, proposing a new cost-efficient using a single-pass batch system. The dosage of dialysis was discussed and set in correlation with blood values in [2].

Oftentimes, mortality is used as a target outcome in the renal context [3] [4] [5]. When it comes to model selection, [6] found a bayes algorithm suitable, while [4] compared regression, random forest and artificial neural networks and proposed the latter for better performance and accuracy. Other models include decision trees [7] and support vector machines [8] [9].

The term *interpretability* in the context of machine learning is defined and its extent discussed in [10]. In [11] methods of getting interpretability into models in the medical context is researched. Especially for the prediction in the ICU, [12] proposes mimic learning as a technique to be used for interpretability.

In the context of this work, we try to unify both the prediction of patient outcomes in the renal context as well as the interpretability of the models used. We compare the results of mimic learning as described in [12] with the results of an interpretable classifier, Bayesian Rule Lists as proposed in [13].

3. Conclusion

The conclusion goes here.

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