PHILIPS LACE+ algorithm

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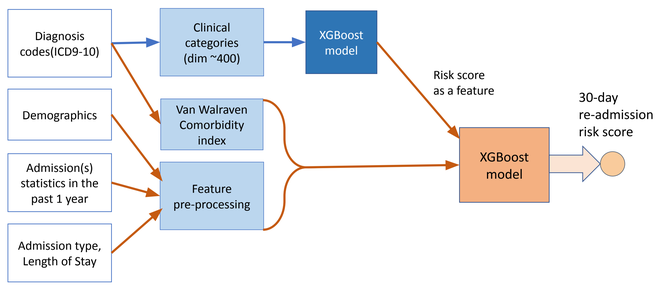
Background

Although the literature on 30-day readmission risk scores is rich and several scores have been developed over the years, predicting re-admissions during a hospital stay for general population remains a key challenge. Most models either perform poorly[1] or requires data that is not easily accessible in real-time.

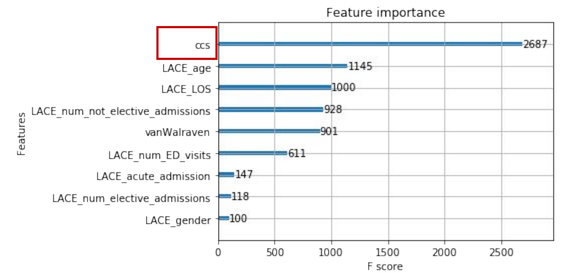
Main improvements of the well-known Canadian LACE+ model[2]

1. train a XGBoost model on US hospital data with more than half a million inpatient encounters from a large multi-states healthcare network
2. Propose a composite two-step prediction model:
   - Step 1: map ICD codes to clinical categories (based on HCUP CSSR[3]) and predict risk of readmission solely based on clinical categories.
   - Step 2: The prediction risk score is added as a feature, replacing Case-mix score suggested in the original LACE+ model.
3. the ability to deal with missing input data elements

Model framework for the improved LACE+ algorithm



Feature importance



Clinical categories (CCS) shows strong prediction power of the 30-day readmission risk

Model performance in various hospitals

Hospital	LACE	Improved LACE+ (Ours)	Number of Encounters
BDMC	0.66	**0.78**	96,770
BUMCP	0.65	**0.77**	110,356
BTMC	0.68	**0.78**	88,709
BBWMC	0.61	**0.7**	51,794
BBMC	0.63	**0.73**	61,280
BDWMC	0.63	**0.73**	55,486
BEMC	0.69	**0.81**	55,003
BGMC	0.7	**0.84**	46,487
NCMC	0.63	**0.77**	32,640
The weighted Average	0.66	**0.772**	598,525 (total)

17% AUC improvement compared to the original LACE+!

Overview of the algorithm execution

Inputs:
- Age
- Gender
- Num of ED visits in last 6 months
- Num of elective admissions in last year
- Num of non-elective admissions in last year
- Urgent admission (yes/no)
- Length of Stay (LoS)
- ICD codes

Algorithm:
1. Map ICD codes to ~400 clinical categories (CCS), as defined by HCUP
2. Predict readmission, with XGBoost, using CCS only
3. Compute van Walraven index
4. Predict risk of readmission using 7 *LACE+* features + VW index + CCS readmission risk prediction

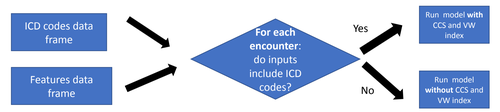
Outputs:
- Readmission risk probability
- SHAP values for each feature
- AUC estimation based on missing data

Visualization of SHAP values example

Algorithm execution logic with missing data elements

Challenge: When ICD codes are missing, we want to output score and indicate algorithm confidence.

Solution:



ENCNTR_ID	Prediction	SHAP LACE age	SHAP LACE gender	SHAP LACE ED visits	SHAP LACE num elective admissions	SHAP LACE num not elective admissions	SHAP LACE LOS	SHAP LACE acute admission	SHAP vanWalraven	SHAP CCS	Model	AUC of Model
1	0.1	-1.2	1	0.8	0.5	2.3	1.1	1	0.2	0.8	with ICD codes	0.77
2	0.05	0.5	NA	0.9	0.9	-1.5	2.5	0	1.7	2	with ICD codes	0.76
3	0.08	0.8	-0.05	-1.2	1.5	-0.9	-2.3	1	-0.8	-2.3	with ICD codes	0.77
4	0.24	1	-0.08	-0.5	-1.2	1.5	1.4	1	NA	NA	without ICD codes	0.735

References

1. Garrison, G. M., Robelia, P. M., Pecina, J. L., & Dawson, N. L. (2017). Comparing performance of 30-day readmission risk classifiers among hospitalized primary care patients. Journal of evaluation in clinical practice, 23(3), 524-529. https://doi.org/10.1111/jep.12656
2. Van Walraven, C., Wong, J., & Forster, A. J. (2012). LACE+ index: extension of a validated index to predict early death or urgent readmission after hospital discharge using administrative data. Open Medicine, 6(3), e80.
3. HCUP Clinical Classifications Software Refined (CCSR) for ICD-10-CM diagnoses, v2021.2. Healthcare Cost and Utilization Project (HCUP). Agency for Healthcare Research and Quality, Rockville, MD. www.hcup-us.ahrq.gov/toolssoftware/ccsr/dxccsr.jsp. Accessed April 4, 2021.