Thesis Proposal

Predictive Modeling with Imbalanced Data

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Outline

Motivation

- Chronic opioid therapy has become an epidemic
- Over 2 million people had a prescription opioid use disorder (2015 National Survey of Drug Use and Health)
- Important to identity patients at high risk
- Allow for hospitals to make informative decisions about prescribing opioids

Imbalanced Learning Problem

- Presents a problem of imbalanced data
- Poor sensitivity with rare outcomes
- Need to improve predictive performance

The Data

- Design: Denver Health retrospective analysis electronic health record (EHR) data from 2008 to 2014.
- Patients: Hospitalized patients at an urban, safety-net hospital.
- Definition of Chronic Opioid Therapy (COT) one year following the index hospital discharge:

  Receipt of $\geq$ 90-day supply of opioids with $<$ 30-day gap in supply over a 180-day period or receipt of $\geq$ 10 opioid prescriptions over one year.

Patient Population

- 27,705 patients
- Majority had incomes <185% of the Federal Poverty Level
- 70% were ethnic minorities
- 5% with COT
- Excluded Patients:
  - <15 or >85 years old
  - Those in prison, jail, or police custody
  - Those who died within one year following their index hospitalization
  - Patients with <2 healthcare visits to Denver Health three years preceding their index hospitalization
  - Undocumented persons receiving emergent hemodialysis
  - Obstetric patients

Table 1

Variable	Yes COT 1,457 (5%)	No COT 26,248 (95%)	p-value
Age 15-35	10%	22%	<.001
Age 45-55	35%	24%	<.001
Age 55-65	28%	21%	<.001
Discount payment or Medicaid	76%	61%	<.001
History of chronic pain	76%	53%	<.001
Discharge diagnosis chronic pain	50%	29%	<.001
Surgical patient	48%	39%	<.001
Benzodiazepine	16%	5%	<.001
Non-opioid analgesics	25%	9%	<.001
Number of opioid prescriptions:			
0	38%	80%	
1	17%	11%	
2	14%	4%	
3	9%	2%	
4-9	23%	3%	<.001
Receipt of opioid at discharge	56%	28%	<.001
MME per hospital day > 10	80%	52%	<.001

Aims

- Accurate predicting $\rightarrow$ improving sensitivity and specificity for imbalanced outcome
- Using and comparing methods of probability cut-points and sampling

Methods

- Create sampled datasets
- Run model on sampled data
- Get predicted probabilities on the test data
- Optimize probability cutoff for outcome

Model

- Roughly 2/3 temporal split of data to get train and test set
- Cross validated lasso regression

Lasso

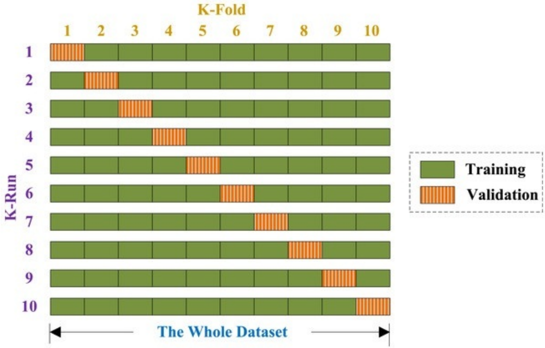
- Lasso:
  - Shrinks estimates
  - Performs variable selection when shrunk to 0

$$\hat{\beta}_{lasso} = argmin \sum_{j=1}^{N} (y_i - \beta_0 - \sum_{j=1}^{p} x_{ij}\beta_j)^2$$

subject to $\sum_{j=1}^{p} |\beta_j| \leq t$ where t is the tuning parameter.

Cross Validation

- Cross validation:
  - Find the best "tuning measure" for model selection which determines amount of shrinkage of estimates
  - Split data into k parts and then train on each of those except one you validate against
  - Then pick the tuning measure that minimizes error



Advantages and Disadvantages

- Advantages:
  - Lower variance of the predicted values
  - More accurate predictions
  - Reduces the number of predictors
- Disadvantages:
  - Biased coefficients, inference not same as logistic regression
  - No standard errors or p-values out of the model

ROC & Cutoff Probabilities

ROC (with pROC package):

- ROC curve plots sensitivity vs specificity for each cut-off
- Top left corner is ideal
- Youden Index is the furthest upper left corner or “max”

ROC Curve

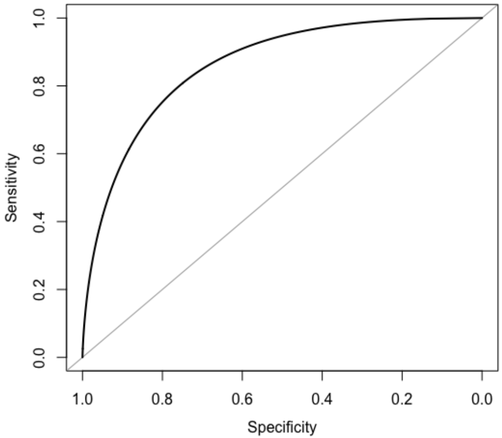


Figure 2: ROC Curve

Confusion Matrix

Correctly identify those w/ outcome:

$$Sensitivity = \frac{TP}{TP + FN}$$

Correctly identify those w/o outcome:

$$Specificity = \frac{TN}{TN + FP}$$

Correctly identify either group:

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

		Predicted class	
		P	N
Actual Class	P	True Positives (TP)	False Negatives (FN)
	N	False Positives (FP)	True Negatives (TN)

First approach

No Sampling, Optimize Cut-off:

- Use original unsampled data and get predictions from the lasso model
  - Predictions return probability between 0 and 1 for each observation
- Use 0.5 standard probability cutoff to compare
- Find “best” probability cutoff
  - Youden Index

Second Approach

Sampling:

- Create sampled data sets that are balanced
  - Down sample
  - Up sample
  - SMOTE
- Predict and use both standard 0.5 and Youden Index as cutoff

Down Sampling

- Under-sample majority to equal minority

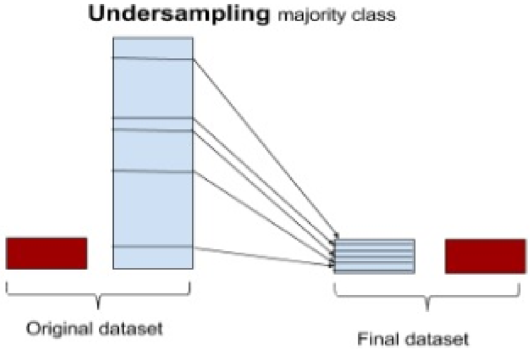


Figure 3: Down sample

Up Sampling

- Over-sample minority to equal majority

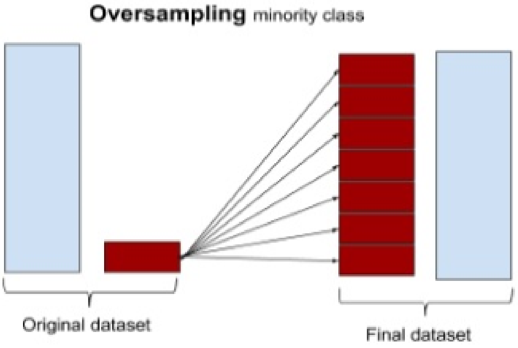


Figure 4: Up sample

SMOTE

- Synthetic Minority Over-sampling Technique

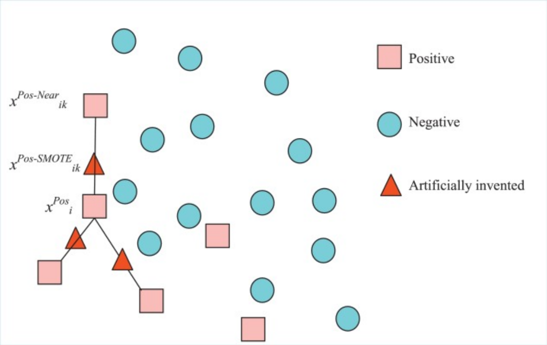


Figure 5: SMOTE

Results

Table 1: Results

Data	Threshold	Specificity	Sensitivity	NPV	PPV	Accuracy	AUC	Covariates
Unsampled 0.5	0.5	99	8	96	35	96	86	31
Unsampled	0.043	73	85	99	12	73	86	31
Down sampled 0.5	0.5	81	75	99	15	81	86	34
Down sampled	0.401	73	85	99	12	74	86	34
Up sampled 0.5	0.5	82	75	99	15	82	87	34
Up sampled	0.399	74	85	99	12	74	87	34
SMOTE 0.5	0.5	86	71	99	17	85	86	33
SMOTE	0.472	84	74	99	17	84	86	33

ROC Plot

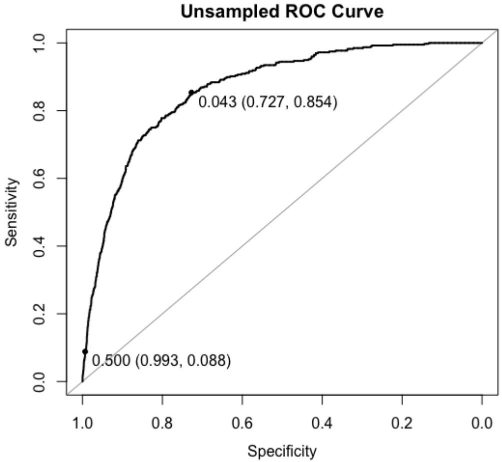


Figure 6: ROC for Original Data: Younden and 0.5 cutoffs

Conclusions Thus Far

- Seeing similar results for both methods
- Depening on situation the clinician may like different sensitivity/specificity
- Some may want to be more conservative, others may not
  - Example: cancer patients in significant pain

Moving Forward

- Bagging (bootstrap aggregating)
  - Model averaging approach
- Stacking
  - Algorithm averaging approach
- Simulation of different percentages for rare outcomes
  - Explore method performance at 5%, 10%, 50% ect. of outcome
- Investigate other sampling techniques or cut-point methods

Timeline

Make changes and additions by January

Finalize paper in Februrary

Defend in March

Questions?

Questions or Suggestions?

References

http://dx.doi.org/10.15585/mmwr.mm655051e1

http://wonder.cdc.gov

https://rasbt.github.io/mlxtend/user_guide/evaluate/confusion_matrix/

https://svds.com/learning-imbalanced-classes/