Increasing survey response rates and decreasing costs by combining numeric and text mining strategies on survey paradata

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6th WORKSHOP: ADVANCES IN ADAPTIVE AND RESPONSIVE SURVEY DESIGN: FROM THEORY TO PRACTICE

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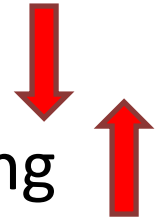
Research Problem from American Community Survey (ACS) Operations

- Multi-dimensional problem
  - Response rates are declining
  - Data collection costs are rising 
  - Respondent burden cannot increase beyond a threshold when field representative contacts respondents who have not completed the survey
- Leads to a multi-objective optimization problem with conflicting objectives
  - We present first steps to solve this problem

Research question and solution approach

- **Predict response propensity, decrease cost, and not increase respondent burden -- using both numeric and textual information (structured and unstructured)**
  - CHI: Structured
  - Case Notes: free form text, unstructured
  - Combine and use CHI (Contact History Information) and Case Notes information
- CHI based response propensity modeling for ACS (new)
- Case Notes based response propensity model (new)

Data and merging CHI with Case Notes

- 2017 ACS CHI and Case Notes (focus of current analysis)

- Each CHI record was merged with zero-many Case Notes associated with that contact attempt
- Challenge: CHI and Case Notes captured on different systems
  - Merged on control number, date and timestamp
  - Timestamp does not match
  - Manually verified large (>400) samples to identify pattern of linkage
  - Custom linkage algorithm based on control number, date and proximity of timestamp between CHI and Case Notes

Distribution of CHI codes in 2017 ACS

Group	Outcome Code	Percent	% HH with Code
1 - new/salvaged	200	1.00%	3.00%
1 - new/salvaged	583	0.02%	0.02%
2 - completed	201	11.51%	45.20%
3 - incomplete	203	0.49%	1.92%
3 - incomplete	206	5.07%	19.46%
3 - incomplete	202	54.34%	70.89%
3 - incomplete	204	0.90%	2.49%
3 - incomplete	208	1.84%	3.77%
4 - Type A non-interview	213	0.20%	0.73%
4 - Type A non-interview	214	0.08%	0.30%
4 - Type A non-interview	216	1.10%	3.62%
4 - Type A non-interview	217	0.08%	0.28%
4 - Type A non-interview	218	2.29%	7.28%
4 - Type A non-interview	219	2.19%	7.28%
5 - Type B/C non-interview	233	0.08%	0.30%
5 - Type B/C non-interview	229	0.06%	0.23%
5 - Type B/C non-interview	240	0.48%	1.76%

Group	Outcome Code	Percent	% HH with Code
5 - Type B/C non-interview	241	0.42%	1.54%
5 - Type B/C non-interview	243	0.25%	0.92%
5 - Type B/C non-interview	244	0.04%	0.15%
5 - Type B/C non-interview	245	0.04%	0.16%
5 - Type B/C non-interview	248	0.42%	1.51%
5 - Type B/C non-interview	253	0.28%	0.99%
5 - Type B/C non-interview	254	0.48%	1.73%
5 - Type B/C non-interview	255	0.07%	0.26%
5 - Type B/C non-interview	258	0.06%	0.22%
6 - Vacant/Temp. Occupied	301	6.23%	24.11%
6 - Vacant/Temp. Occupied	501	0.16%	0.61%
6 - Vacant/Temp. Occupied	305	0.81%	1.82%
7 - mailed/onine/given to fld rep	308	2.69%	4.57%
7 - mailed/onine/given to fld rep	309	2.93%	9.94%
7 - mailed/onine/given to fld rep	310	0.61%	1.25%
Other	313	0.82%	2.17%
Other	580	1.96%	6.51%

n=774,000

Predictive Model: Logistic Regression

- **Predict:** Final outcome – 201 (completed) vs 218 (refused)
- Prediction based on information from 1st contact only (personal or telephone)
- **Model 1:** Predictors: Case Notes
  - Field Rep. Case Notes (textual data)
- **Model 2:** Predictors: Admin and CHI variables
  - Census region, interview period (month), roster indicator (Administrative control vars.)
  - Partial/unable to conduct (H##), Language
  - Concern/behavior/reluctance (B##)
  - Noncontact telephone (P##), noncontact personal visit (V##)
  - Strategies attempted (Q##)
  - Includes interaction effects
- **Model 3:** Predictors: Admin and Case Notes
- **Model 4:** Predictors: Admin, CHI variables and Case Notes

Primer: Natural Language Processing (NLP)

- NLP is a method designed to give mathematical meaning to human language
- Extremely powerful
- NLP can be used to identify
  - Parts of speech (Noun, Verb)
  - Entities (Person, Place, Organization)
  - Tokens of related words (San and Francisco probably combined to San Francisco)
  - Probability of words appearing in a corpus of text
  - Probability of word associations
    - e.g. ‘England’ and ‘Queen’ should be more common than pairing ‘England’ and ‘Sunshine’

Cleaning

[common words, punctuation, etc.]

Create terms

- parts of speech
- Stemming
- others

Calculate term frequency (TF)

term

document

Predicting with textual data

Predictive models

- Logistic regression
- Random forest
- etc.

Weighted matrix (TF-IDF)

weighted term

document

normalized matrix

Weighted value of term (IDF)

[Varies inversely with number of documents the term appears in]

Term Frequency–Inverse Document Frequency (TF-IDF) primer

Term Document Matrix					
	term				
doc	cat	dog	grooming	best	total terms/doc
A	4	12	0	7	3
B	4	9	10	2	4
C	6	0	8	1	3

$$\text{IDF(t)} = \log\_e\left(\frac{Total\ number\ of\ documents}{Number\ of\ documents\ with\ term\ t\ in\ it}\right)$$

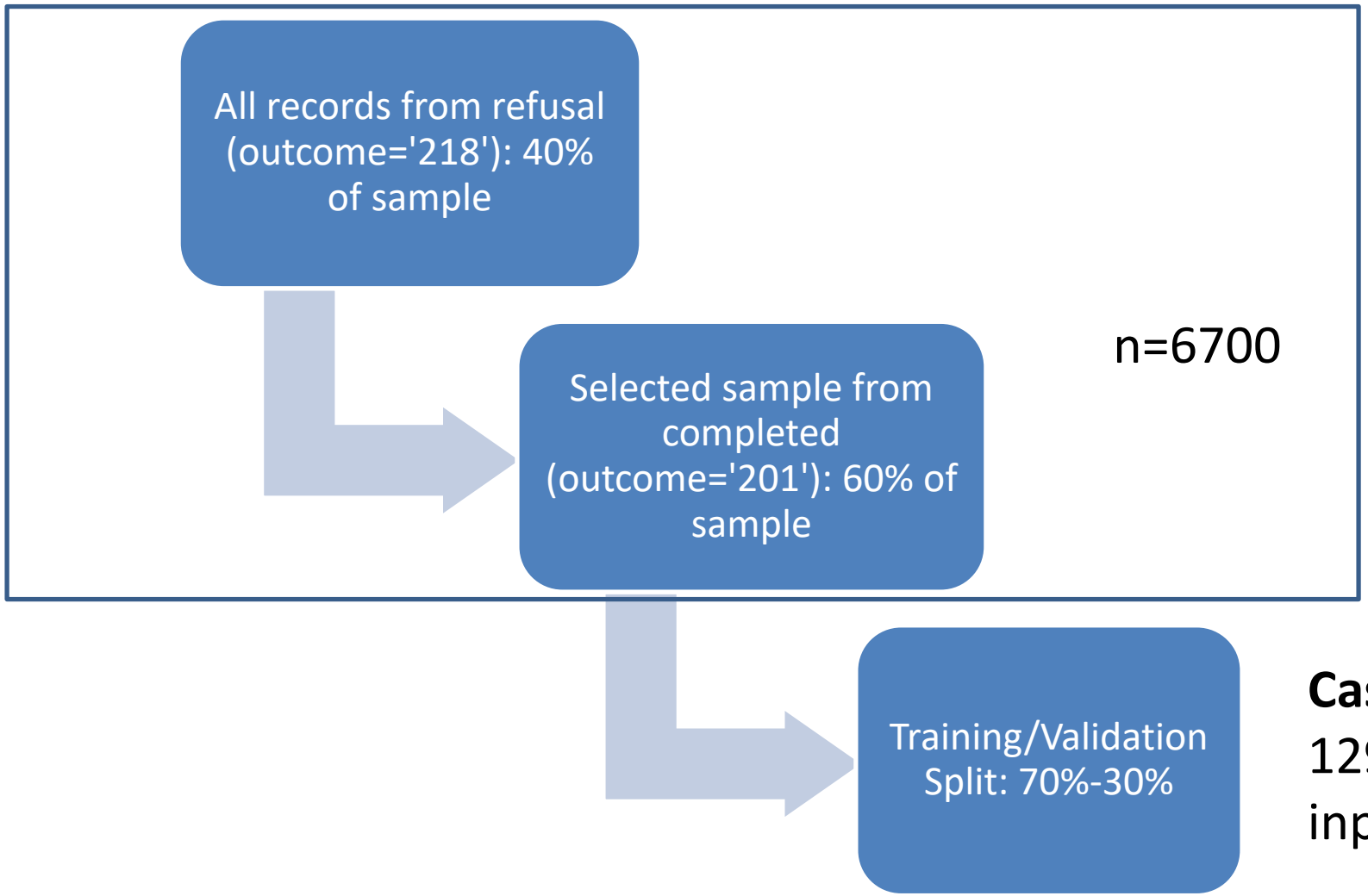
IDF			
cat	dog	grooming	best
1	1.405465	1.405465	1

$$\text{TF} = \frac{Number\ of\ times\ term\ t\ appears\ in\ a\ document}{Total\ number\ of\ terms\ in\ the\ document}$$

Term Frequency Matrix				
doc	cat	dog	grooming	best
A	1.333	4	0	2.333
B	1	2.25	2.5	0.5
C	2	0	2.666667	0.333

TF-IDF [TF]*[IDF]				
doc	cat	dog	grooming	best
A	1.333333	5.62186	0	2.333333
B	1	3.162296	3.513663	0.5
C	2	0	3.747907	0.333333

Prediction model dataset setup



Case Notes:
129,000 TF-IDF input vectors

Comparing Text-only vs. CHI-only model results

Model 1: Case Notes

	Predicted Outcome		Accuracy
Actual Outcome	**1**	**0**	0.6337
1	0.5213	0.0777	
0	0.2886	0.1124	

Model 2: Admin and CHI variables

	Predicted Outcome		Accuracy
Actual Outcome	**1**	**0**	0.628
1	0.5498	0.0405	
0	0.3315	0.0782	

Top 30 terms associated with completion			
nice	spanish	letter_brochures	mother
left_business	return	opened	internet_spending
nis	partial	scheduled	ltr_note
geo	Monday	left_materials	personal_letter
left_intro	around	vehicles	mis
transmit	son	accessor	trailer
env	agreed	note_online	
left_online	today	kids	

Top 30 terms associated with refusal			
refused	shut	gate	card_brochure
interested	government	tell	participate
send	she	reluctant	explaining
send_internet	it	intercom	shut_door
doorman	male	big	place
answered_door	online	find_nobody	lft_pkt
refusal	line	explain	
closed_door	attempted	census_letter	

Model metrics comparison

Model	Description	Accuracy	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
1	Case Notes	**0.634**	0.870	0.280	0.644	0.591
2	Admin + CHI Variables	0.628	**0.931**	0.191	0.624	**0.659**
3	Admin + Case Notes	0.602	0.752	0.387	0.639	0.520
4	Admin + CHI Variables + Case Notes	0.611	0.756	**0.404**	**0.646**	0.534

Conclusion and next steps

- Promising results from Case Notes predictive model
  - Used only 1st contact information to predict eventual outcome
  - Used only 2017 ACS paradata
  - Available 2015 and 2016 datasets – to augment for next set of analysi
- Fine-tuning number of terms to use in model
  - Also different types of vectorization methods
- Working on models where information taken from 1st and 2nd contact
  - Challenge: Decreases training dataset size
- Investigating other models including Markov decision models

BACKUP

Model metrics comparison

Model 1: Case Notes			
	Predicted Outcome		Accuracy
Actual Outcome	1	0	0.6337
1	0.5213	0.0777	
0	0.2886	0.1124	

Model 2: Admin and CHI variables			
	Predicted Outcome		Accuracy
Actual Outcome	1	0	0.628
1	0.5498	0.0405	
0	0.3315	0.0782	

Model 3: Admin and Case Notes			
	Predicted Outcome		Accuracy
Actual Outcome	1	0	0.6023
1	0.4437	0.1466	
0	0.2511	0.1586	

Model 4: Admin, CHI and Case Notes			
	Predicted Outcome		Accuracy
Actual Outcome	1	0	0.6114
1	0.4461	0.1442	
0	0.2444	0.1653	