



Newsletter Churn Prediction

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Addressing the Dataset

- Feature extraction and data wrangling to determine relevant features (many features not usable)
- Data is unbalanced, the majority of users were remaining subscribed
- Different data transformations proved to be useful for the different models, as well as different features

Profile Id	Domain	Engagement	Signup	Opens	Clicks	Last Open	Last Click	Optout Time	Geolocation	Geolocation	State	Geolocation	Country	Geoc Lifetime	Message	Top Device	referral	so	first_name	last
55726559	shglobal.n	hardboun	6/6/2015 9:53	51	11	1/20/2016 0:35	8/12/2015 19:50		El Dorado	CA	US		US	9576:	169 Other	DMi	Betty			
54411116	hotmail.co	optout	10/17/2014 8:52	2	0	11/21/2014 7:37		11/21/2014 7:45							203	Untagged				
560e9d9d	yahoo.com	optout	2/24/2016 12:35	0	0			3/2/2016 19:45							10	DMi	Ana		Alvi	
576d2986	gmail.com	dormant	9/24/2016 9:41	0	0										257	Facebook				
5498bd77f	shglobal.n	optout	12/22/2014 19:55	30	1	1/6/2015 21:10	1/1/2015 21:21	1/6/2015 21:11				US			39 Android	In Book Ad				
5784fbad	hotmail.co	passive	10/7/2016 21:45	54	29	4/17/2017 15:29	4/6/2017 10:34		Birmingham	MI	US		US	4800:	235 Chrome	In Book Ad				
573926e7	yahoo.com	optout	5/20/2016 10:42	16	0	5/25/2016 20:24		5/25/2016 20:26							9	Liveint				
556fb952	gmail.com	disengaged	9/14/2015 12:53	16	0	2/5/2017 20:51									632	DMi	Rose		Des	
543dbaf71	hotmail.co	hardboun	10/1/2014 19:15	0	0										1	Untagged				
547240a36	yahoo.com	hardboun	11/23/2014 15:16	0	0										1	Facebook				
549175a1	ymail.com	optout	12/17/2014 7:51	31	5	4/30/2016 9:31	1/1/2016 12:53	4/30/2016 9:32	Evansville	IN	US		US	8293:	438 iPad	Facebook				
58446929C	ad.com	passive	12/4/2016 19:47	164	20	4/19/2017 12:46	3/15/2017 20:20		New York	NY	US		US	1002:	164 Android	Tablet				
5631559f	yahoo.com	optout	10/28/2015 19:09	20	2	11/24/2015 10:30	10/30/2015 11:08	11/24/2015 10:30	Stockton	CA	US		US	9520:	20 iPhone	In Book Ad				
567665c9f	hotmail.co	disengaged	12/20/2015 3:24	11	0	1/10/2017 11:58									540	DMi	Sandra		Heb	
53bed8281	yahoo.com	dormant	8/13/2014 17:27	0	0										1335	Untagged				
56a9647a1	yahoo.com	optout	1/27/2016 19:44	0	0			2/11/2016 15:18							20	DMi	Lynn		Mfn	
58b5697bc	gmail.com	active	2/28/2017 7:13	45	23	4/19/2017 13:36	4/17/2017 13:33		Killington	VT	US		US	0575:	66 Chrome	Liveint				
568ca7e4a	gmail.com	dormant	1/6/2016 5:09	0	0										258	DMi	Monique		lives	
56a82b95c	gmail.com	disengaged	1/26/2016 21:29	74	0	2/3/2017 9:44									525	DMi	danielle		chap	
539c552f6	gmail.com	optout	8/24/2014 6:58	56	1	5/31/2015 17:46	6/1/2015 8:10	6/1/2015 8:11				US			859 Android	Untagged				
56edd121i	gmail.com	dormant	3/19/2016 18:13	0	0										219	Liveint				
56a2a3835	verizon.net	optout	1/22/2016 21:20	29	51	3/19/2016 10:19	6/24/2016 9:55	6/26/2016 15:47	Thousand	CA	US		US	9136:	173 iPad	In Book Ad				
5526941e1	yahoo.com	disengaged	4/9/2015 13:17	1	0	11/17/2015 19:46									622	Permission	Teresa		Saff	
58e7ec722	yahoo.com	passive	4/7/2017 15:45	2	0	4/15/2017 22:04									17	torsweeps				
578154bdc	verizon.net	optout	7/9/2016 15:47	51	0	8/13/2016 21:08		8/6/2016 12:54							33	Liveint				
585570095	comcast.ne	optout	12/17/2016 12:04	7	0	1/21/2017 11:33		1/21/2017 11:33							42	Liveint				
549b4276f	yahoo.com	optout	12/24/2014 17:47	7	0	1/6/2015 9:55		1/5/2015 9:55							29	Facebook				
5700c124	shglobal.n	optout	4/11/2016 16:41	2	0	4/13/2016 11:02		4/13/2016 11:02							2	BookItSwags				
544a5e0f	ad.com	hardboun	10/24/2014 20:59	0	0										1	Untagged				
585162277	gmail.com	passive	12/14/2016 10:15	55	4	4/17/2017 22:36	3/29/2017 15:09		Decatur	GA	US		US	3003:	155 Android	Google				
58e7ec92	verizon.net	dormant	4/7/2017 15:45	0	0										11	torsweeps				
56a021c71	gmail.com	dormant	1/20/2016 19:09	0	0										241	DMi	edric		coe	
56e8d8eb	gmail.com	disengaged	3/14/2016 11:29	1	0	6/9/2016 9:51									437	DMi	Ryan		Gan	
54208961	comcast.ne	optout	9/23/2014 16:29	622	77	6/12/2016 23:20	11/11/2015 13:30	4/14/2016 10:21	Mechanical	PA	US		US	1705:	1015 Android	Ta Facebook				
54a64095	yahoo.com	disengaged	1/2/2015 11:18	2	5	1/27/2015 12:18	1/27/2015 12:19		Barberton	OH	US		US	4430:	24 iPhone					
55ca1129	gmail.com	optout	8/11/2015 11:17	4	0	8/17/2015 11:04		8/17/2015 11:05							5	DMi	Bee		Pan	
569e18dd	gmail.com	optout	1/18/2016 11:54	2	0	3/2/2016 19:15		3/2/2016 19:16							51	DMi	Megan		Rus	
58c795a20	ad.com	disengaged	12/27/2016 18:13	2	0	2/23/2017 13:37									142					

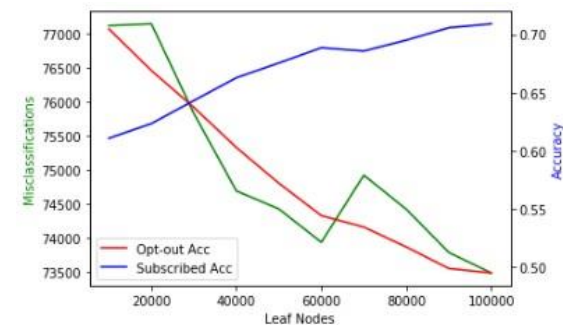
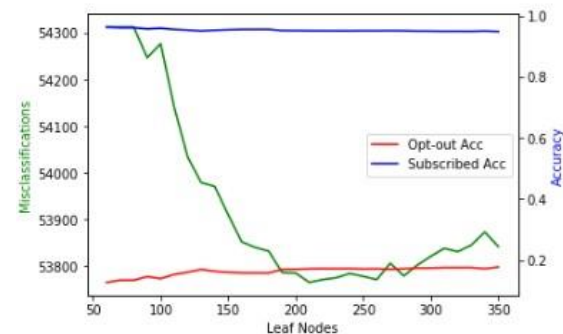
Decision Tree

- Used relevant features and got unbalanced results
 - Minimal misclassifications at 210 leaf nodes
 - Great subscriber accuracy with poor opt-out accuracy

```
Test Opt-out Percent Correct: 0.17116292427261143
Test Subscribed Percent Correct: 0.951306222766972
Test Misclassifications: 53765
```

- Class weights of tree were balanced
 - More misclassifications than unbalanced tree
 - Less gap in the accuracy of predicted Opt-out and Subscribed users
 - Misclassifications continue to decrease as max nodes increases

```
Test Opt-out Percent Correct: 0.5440920431497137
Test Subscribed Percent Correct: 0.6885279565683337
Test Misclassifications: 73937
```



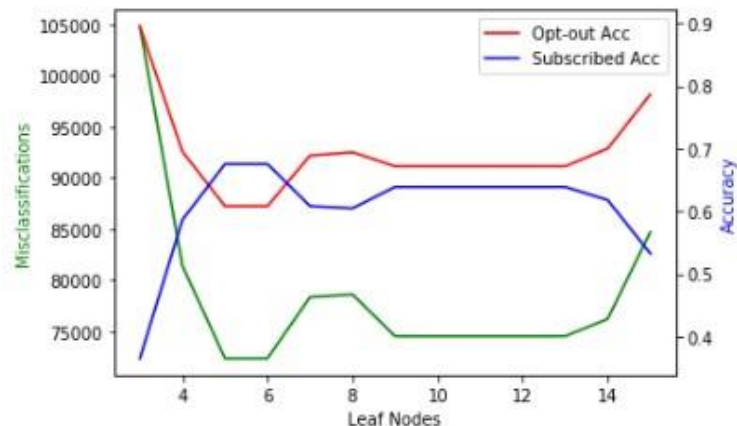
Decision Tree Improvement

Problems:

- Model training time is very high
- Final tree is very complex with no optimal max leaf nodes
- Accuracy of model still suffered

Discovered Solution:

- Initial inclusion of the large amount of one-hot encoded user genre preference features helped lower misclassifications before class weights were balanced
- After balancing the weights these features harmed the accuracy of the model while making the model overly complex
- Removal of preference features greatly simplified model and improved accuracy
- Max leaf nodes was optimized at 5
- A defined max depth only hindered the accuracy
- Other variables such as minimum samples for a split and minimum samples per leaf had no effect on outcome



```
Training Opt-out Percent Correct: 0.609967796350253
Training Subscribed Percent Correct: 0.6751996255300402
Test Opt-out Percent Correct: 0.6083140380162619
Test Subscribed Percent Correct: 0.6755331095866676
Test Misclassifications: 72384
```

Decision Tree Conclusion

If the goal was to minimize misclassifications:

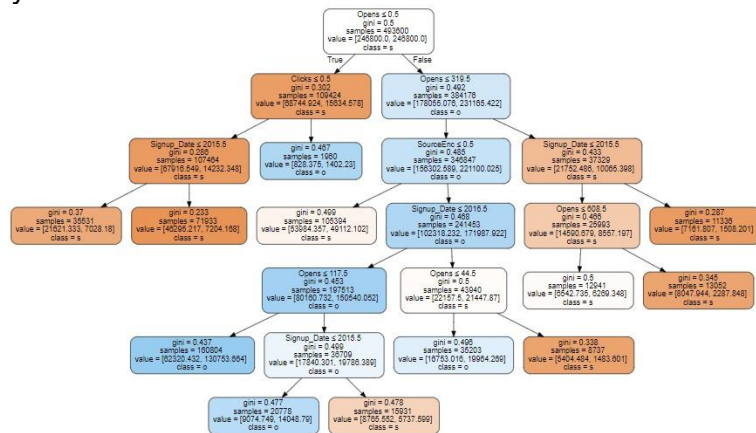
- Balancing the class weights would hurt the results
- Subscriber prediction accuracy excels at the cost of the opt-out accuracy

With a goal of predicting users who will potentially opt-out:

- Balancing class weights puts an emphasis on equal accuracy for classification
- More useful outcome since the model attempts to accurately predict opt-out users

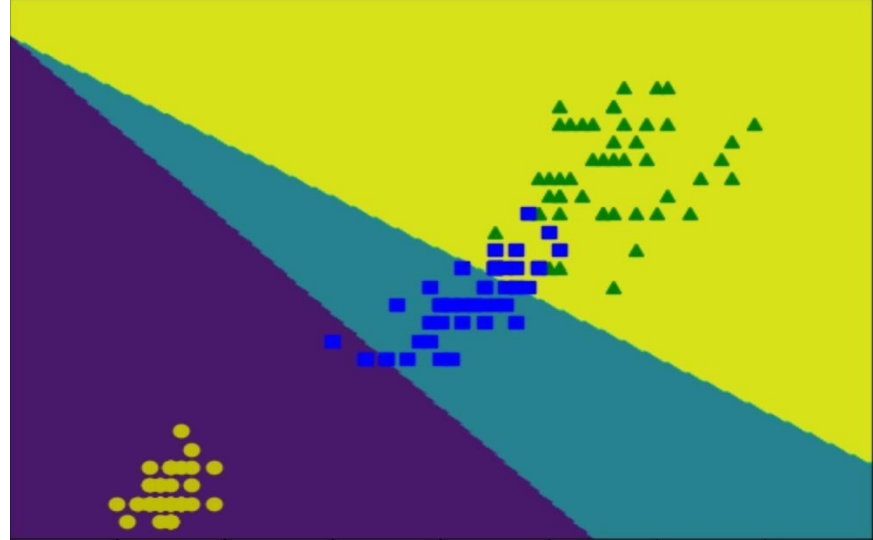
Takeaways:

- An overly complex model will lead to little information gain with each split
- Even after all attempted optimization, a decision tree is most likely the ideal model for the task

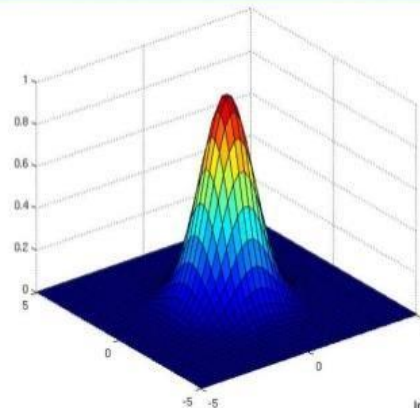


SVM

- Standard SVC from scikit-learn too slow, hard to test with multiple parameters due to long training times
- Used LinearSVC, got imbalanced results(very low accuracy for predicting optouts, and very high accuracy for predicting subscribers)
- Used Nystroem kernel approximation paired with a LinearSVC, and RBFSampler kernel approximation paired with SGDClassifier; results were still not good
- The above 2 models behave similar to an SVM with an RBF kernel, but with much faster training times
- Attempted an ensemble of all the above models using a VotingClassifier ;no improvement
- Attempted to loop through all possible parameters for most of the above models; no improvement



The Gaussian RBF Kernel



$$K(\vec{x}, \vec{l}^i) = e^{-\frac{\|\vec{x} - \vec{l}^i\|^2}{2\sigma^2}}$$

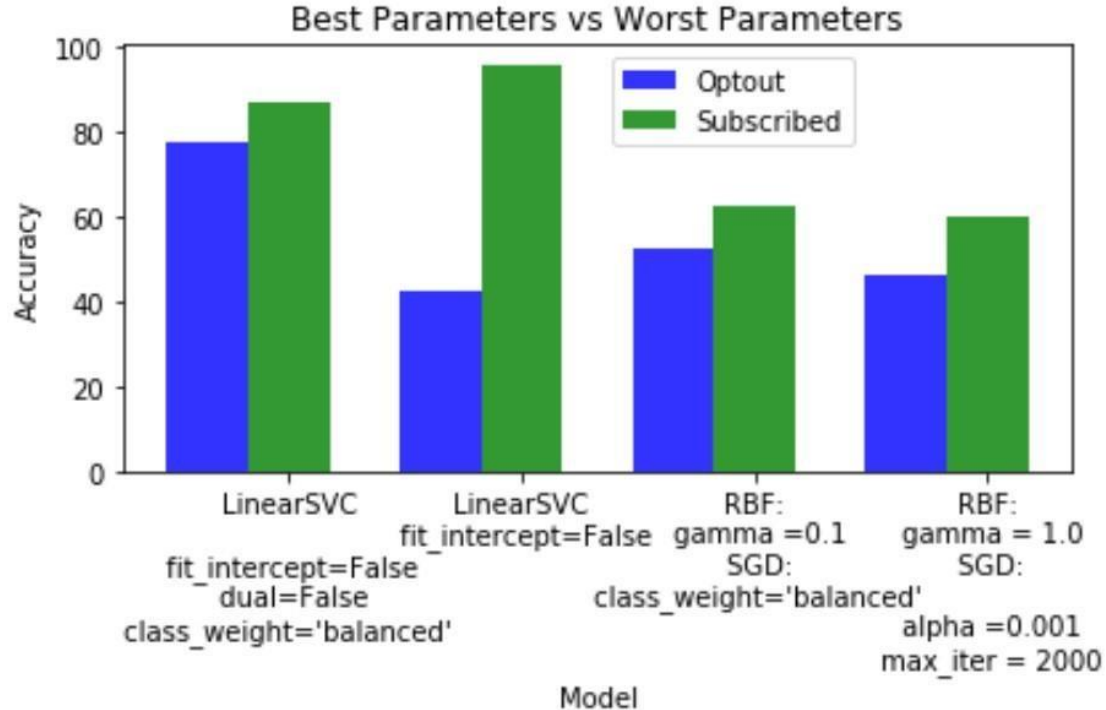
Image source: <http://www.cs.toronto.edu/~duvenaud/cookbook/index.html>

Solution

- Dropped most of the above models; kept only 3 which seemed to show slightly better results more consistently
- The format of the data, it's imbalanced examples and the features used were the problem
- Applied One-Hot-Encoding and changed other features of the dataset to suit the selected models
- Dropped a few features, included some which were not used earlier
- Tuned the parameters and narrowed down the useful models to 2 with the below parameters:
 - `LinearSVC(fit_intercept = False, dual = False, class_weight = 'balanced')`
 - `RBFSampler(gamma= 0.1, random_state=1); SGDClassifier(max_iter=1000, class_weight = 'balanced')`
- LinearSVC provided the highest accuracy, RBFSampler with SGDClassifier was good enough to be included as well

SVM-Final Results

- LinearSVC produced a good accuracy of 77.3% for Optout and 85.1% for Subscribed with the best parameters
- RBF+SGD produced a mediocre accuracy of 53% for Optout and 62% for Subscribed with the best parameters

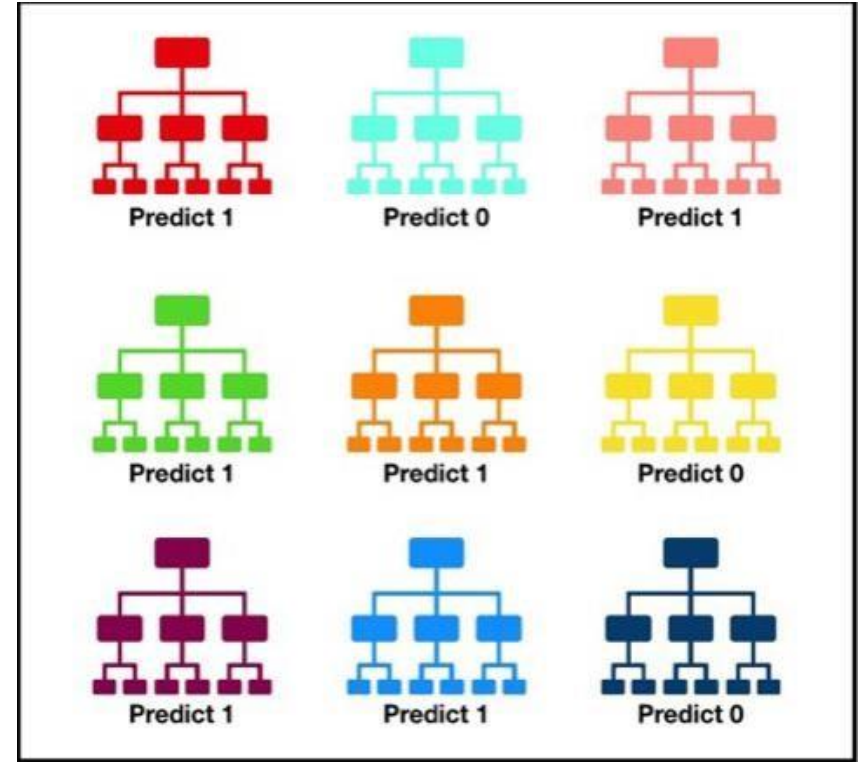


Random Forest

- Random Forest consists of a large number of individual decision trees that operate as an ensemble
- Each tree gives us a class prediction and the class with the most votes becomes our prediction
- Random Forest uses bagging and random features when building the individual trees to create a forest of uncorrelated trees

Feature Extraction

- Recursive Feature Extraction (RFE):
 - Retrieving the top 3 features using the logistic regression algorithm



Tally: Six 1s and Three 0s

- The features taken into account are:
 - Profile.Id,Signup,Last.Open,Last.Click,Opt out.Time,Opens,Clicks,Lifetime.Message,referral_source,Top.Device,Geolocation.City,Domain
- The target variable is the 'Engagement'
- Retrieving the 3 most favorable features with the following ranks:

```
In [16]: model = LogisticRegression(solver='lbfgs')
rfe = RFE(model, 3)
fit = rfe.fit(X, Y)
print("Num Features: %d" % fit.n_features_)
print("Selected Features: %s" % fit.support_)
print("Feature Ranking: %s" % fit.ranking_)
```

```
Num Features: 3
```

```
Selected Features: [False  True  True False  True False False False False False False]
```

```
Feature Ranking: [10  1  1  2  1  5  6  7  8  9  4  3]
```

- Random Forest Algorithm produced an accuracy of 96.5% for subscribed and 80% for optout, which is the highest of all 3 types of models.

Conclusion

Decision Tree

- Opt-out Accuracy: 60.8%
- Subscribed Accuracy: 67.6%

SVM

- Opt-out Accuracy: 77.3%
- Subscribed Accuracy: 85.1%

Random Forest

- Opt-out Accuracy: 96.5%
- Subscribed Accuracy: 80%

References

1. <https://towardsdatascience.com/optimizing-hyperparameters-in-randomforest-classification-ec7741f9d3f6>
2. https://scikit-learn.org/stable/modules/kernel_approximation.html
3. <https://www.geeksforgeeks.org/ml-one-hot-encoding-of-datasets-in-python/>
4. http://chrisstrelhoff.ws/sandbox/2015/06/08/decision_trees_in_python_with_sci_kit_learn_and_pandas.html
5. <https://towardsdatascience.com/understanding-random-forest-58381e0602d2>