Machine Learning Engineer Nanodegree

Capstone Project

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Definition

Project Overview

DonorsChoose.org receives hundreds of thousands of project proposals each year for classroom projects in need of funding. A large number of volunteers is needed to manually screen each submission before it's approved to be posted on the DonorsChoose.org website.

Next year, DonorsChoose.org expects to receive close to 500,000 project proposals. As a result, there are three main problems that need to be solved:

1. How to scale current manual processes and resources to screen 500,000 projects so that they can be posted as quickly and as efficiently as possible.
2. How to increase the consistency of project vetting across different volunteers to improve the experience for teachers.
3. How to focus volunteer time on the applications that need the most assistance.

Problem Statement

Predict whether or not a DonorsChoose.org project proposal submitted by a teacher will be approved, using the text of project descriptions as well as additional metadata about the project, teacher, and school. DonorsChoose.org can then use this information to identify projects most likely to need further review before approval.

Metrics

Model will be evaluated on area under the ROC curve between the predicted probability and the observed target.

Analysis

Data Exploration

The competition dataset contains information from teachers' project applications to DonorsChoose.org including teacher attributes, school attributes, and the project proposals including application essays. Your objective is to predict whether or not a DonorsChoose.org project proposal submitted by a teacher will be approved.

File descriptions

train.csv - The training set.
test.csv - The test set.

resources.csv - Resources requested by each proposal; joins with test.csv and train.csv on id.
sample_submission.csv - A sample submission file in the correct format.

Data fields

test.csv and train.csv:

- id - Unique id of the project application.
- teacher_id - Id of the teacher submitting the application.
- teacher_prefix - Title of the teacher's name (Ms., Mr., etc.).
- school_state - US state of the teacher's school.
- project_submitted_datetime - Application submission timestamp.
- project_grade_category - School grade levels (PreK-2, 3-5, 6-8, and 9-12).
- project_subject_categories - Category of the project (e.g., "Music & The Arts").
- project_subject_subcategories - Sub-category of the project (e.g., "Visual Arts").
- project_title - Title of the project.
- project_essay_1 - First essay*.
- project_essay_2 - Second essay*.
- project_essay_3 - Third essay*.
- project_essay_4 - Fourth essay*.
- project_resource_summary - Summary of the resources needed for the project.
- teacher_number_of_previously_posted_projects - Number of previously posted applications by the submitting teacher.
- project_is_approved - Whether DonorsChoose proposal was accepted (0="rejected", 1="accepted"); (train.csv only).

* Note: Prior to May 17, 2016, the prompts for the essays were as follows:

- project_essay_1: Introduce us to your classroom.
- project_essay_2: Tell us more about your students.
- project_essay_3: Describe how your students will use the materials you're requesting.
- project_essay_4: Close by sharing why your project will make a difference.

Starting on May 17, 2016, the number of essays was reduced from 4 to 2, and the prompts for the first 2 essays were changed to the following:

- project_essay_1: Describe your students: What makes your students special? Specific details about their background, your neighborhood, and your school are all helpful.
- project_essay_2: About your project: How will these materials make a difference in your students' learning and improve their school lives?
- For all projects with project_submitted_datetime of 2016-05-17 and later, the values of project_essay_3 and project_essay_4 will be NaN.

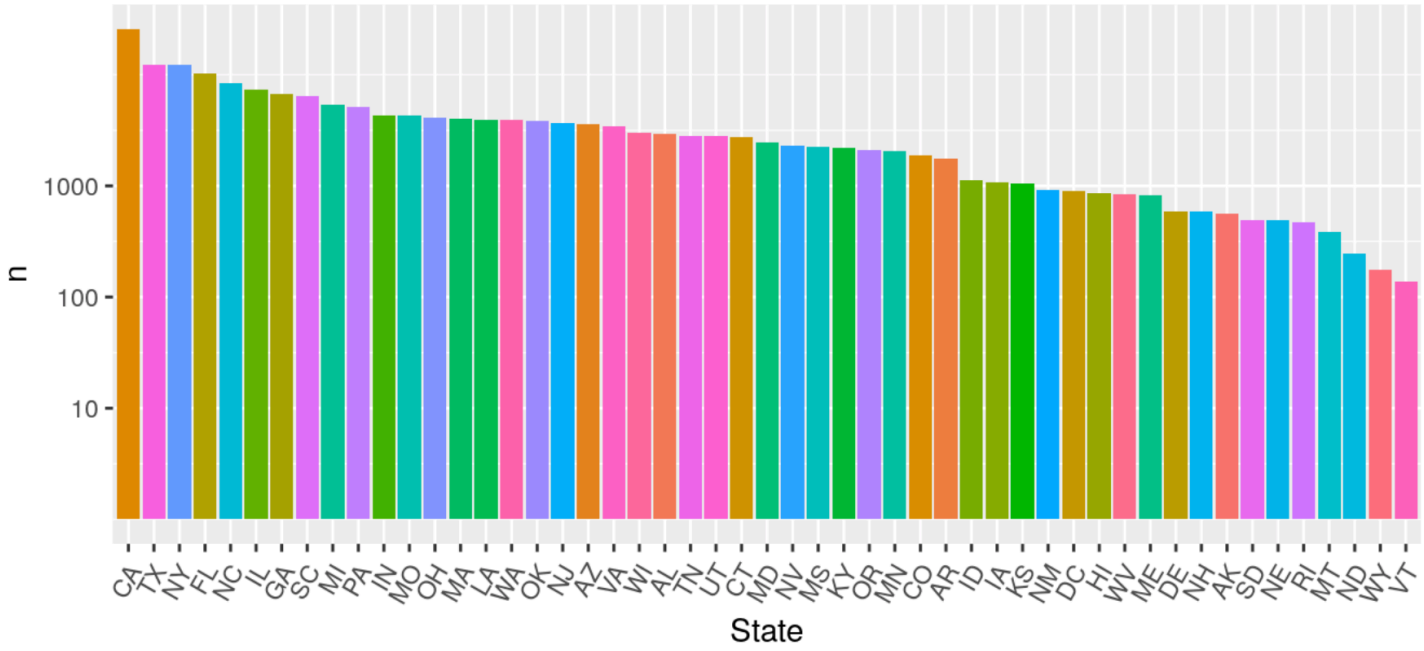
resources.csv:

Proposals also include resources requested. Each project may include multiple requested resources. Each row in resources.csv corresponds to a resource, so multiple rows may tie to the same project by id.

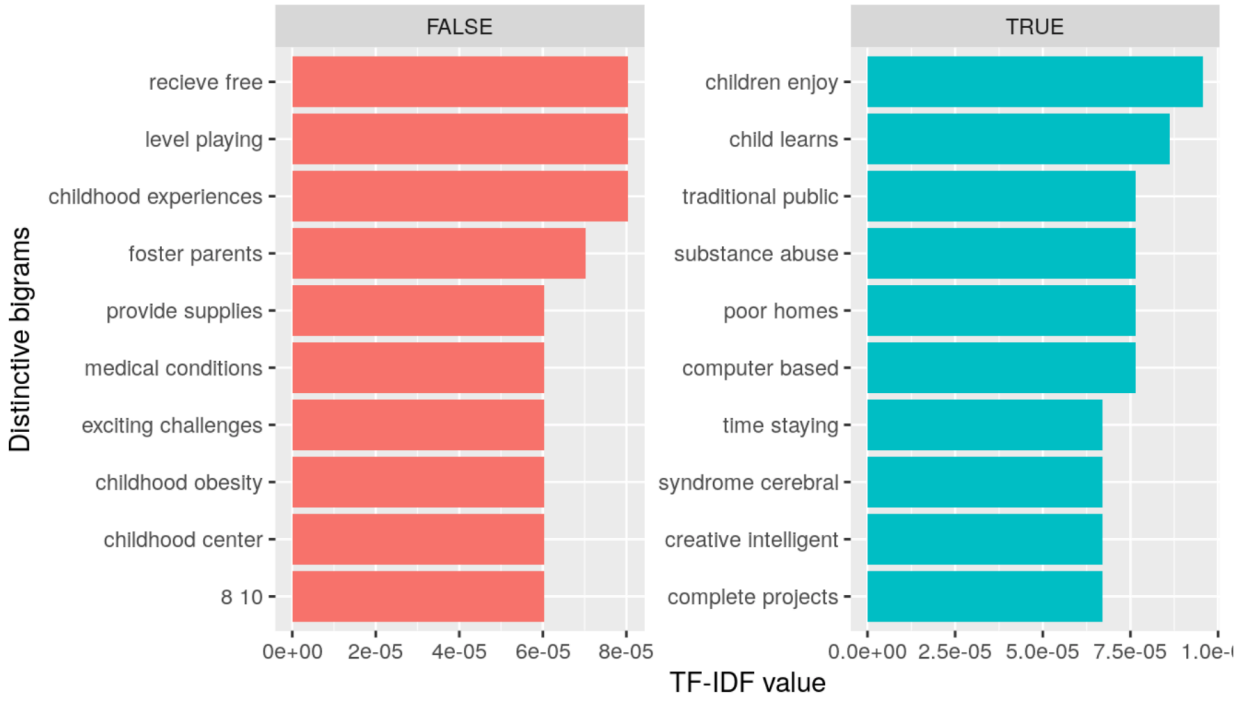
- id - Unique id of the project application; joins with test.csv. and train.csv on id.
- description - Description of the resource requested.
- quantity - Quantity of resource requested.
- price - Price of resource requested.

Exploratory Visualization

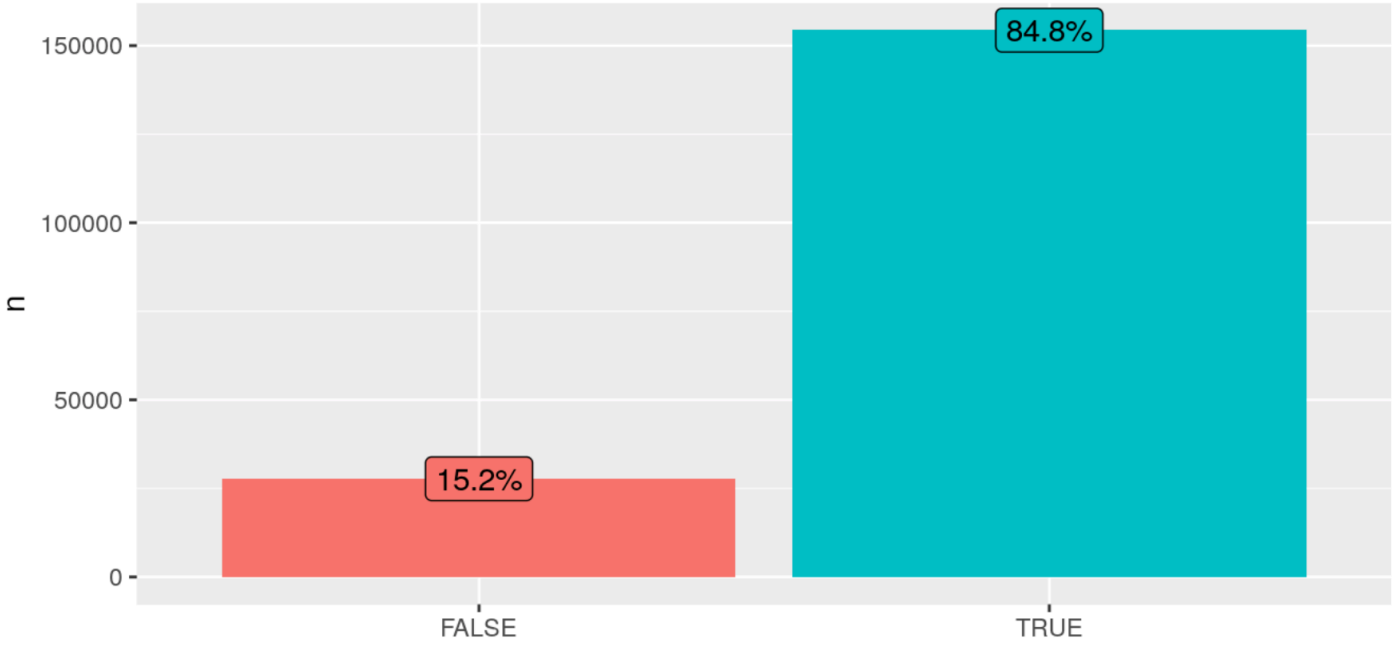
A plot with the number of submitted project proposals across the US states on a log-scale. As we can see, California dominates in the plot while Vermont stands at last place.



'*project_essays*' are most important features in our dataset that give lot of information about the outcome. Since Essays 1 and 2 are dominant we just consider these for analysis. Below plot shows top bigrams after performing TF-IDF on essay 1 and essay 2.



Below plot shows percentage of approvals and rejections. This is based on the target: *project_is_approved*. As we can see approval percentage is much higher (~85).



** Above visualizations are taken from Kaggle kernel - https://www.kaggle.com/headsortails/an-educated-guess-donorschoose-eda

Algorithms and Techniques

Since this is a classification problem and we have multiple features, I choose to use gradient boosted trees to build learning model.

XGBoost is one of the fastest implementations of gradient boosted trees. It looks at the distribution of features across all data points in a leaf and uses this information to reduce the search space of possible feature splits. It also helps us achieve regularization in model.

Benchmark

Kaggle DonorsChoose.org Application Screening competition leaderboard score at the time of proposal submission was 0.79 (Area under receiver operating characteristic curve). By benchmark was to reach score that stands at 30% of public leaderboard, which was 0.74.

Methodology

Data Preprocessing

First, I have processed resource information that was given in resources.csv and a added the result to training and testing sets.

Then, I have encoded 'teacher_id','teacher_prefix','school_state', 'project_grade_category', 'project_subject_categories', ‘project_subject_subcategories' features using LabelEncoder.

Challenging part of the project is to process text. I choose to use TF-IDF for processing text and extract useful information out of it. So as a next step, I have processed 'project_title', 'project_resource_summary', 'project_essay_1', ‘project_essay_2' features using TF-IDF algorithm and added the result to training and testing set.

Finally, I have removed the original features 'id', 'project_is_approved', 'project_resource_summary', 'project_title', 'project_essay_1', 'project_essay_2', 'project_essay_3', 'project_essay_4', 'project_submitted_datetime', 'project_subject_categories', ‘project_subject_subcategories' from training and testing sets as we have already processed them and using transformed results.

Implementation

I have built a basic model to start with. Values that I used are: eta= 0.05, max_depth= 8, test_size=0.3. Training and validations scored for this base model are: train-auc=0.90123, valid-auc=0.739

```
x_train, x_test, y_train, y_test =
model_selection.train_test_split(train[col],train['project_is_approved'], test_size=0.3,
random_state=18)
params = {'eta': 0.05, 'max_depth': 8, 'objective': 'binary:logistic', 'eval_metric': 'auc', 'seed': 18,
'silent': True}
watchlist = [(xgb.DMatrix(x_train, y_train), 'train'), (xgb.DMatrix(x_test, y_test), 'valid')]
model = xgb.train(params, xgb.DMatrix(x_train, y_train), 450,  watchlist, verbose_eval=10,
early_stopping_rounds=20)
```

Refinement

I ran the model with various values by tuning manually. Below are the results:

eta: 0.1, max_depth: 8, test_size=0.3 -> train-auc:0.90394 valid-auc:0.738839
eta: 0.1, max_depth: 7, test_size=0.3 -> train-auc:0.87082 valid-auc:0.738927
eta: 0.1, max_depth: 7, test_size=0.25 -> train-auc:0.882395 valid-auc:0.742017
eta: 0.1, max_depth: 7, test_size=0.25 -> train-auc:0.896722 valid-auc:0.74973
eta: 0.1, max_depth: 6, test_size=0.25 -> rain-auc:0.878008 valid-auc:0.752383

Results

Model Evaluation and Validation

The final model was built with values, eta: 0.1, max_depth: 6, test_size=0.25. Kaggle ROC score after submitting the result generated by this model is 0.75496.

```
x_train, x_test, y_train, y_test =
model_selection.train_test_split(train[col],train['project_is_approved'], test_size=0.25,
random_state=18)
params = {'eta': 0.1, 'max_depth': 6, 'objective': 'binary:logistic', 'eval_metric': 'auc', 'seed':
18, 'silent': True}
watchlist = [(xgb.DMatrix(x_train, y_train), 'train'), (xgb.DMatrix(x_test, y_test), 'valid')]
model = xgb.train(params, xgb.DMatrix(x_train, y_train), 450,  watchlist, verbose_eval=10,
early_stopping_rounds=20)


test['project_is_approved'] = model.predict(xgb.DMatrix(test[col]),
ntree_limit=model.best_ntree_limit)
test['project_is_approved'] = test['project_is_approved'].clip(0+1e12, 1-1e12)
```

Justification

Final model prediction score which is 0.75496 is better compared to the benchmark score of 0.74. Result can be further improved as discussed in conclusion.

Conclusion

Reflection

I choose this problem to get a taste of NLP. Faced lot of challenges with text processing. Working on this made me realize how difficult NLP really is.

Using XGBoost has made it easy for me to train and evaluate result quickly. It was very easy to run multiple experiments as the training the model was fast.

I have completely ignored essay 3 and 4 in my model. As they looked less significant compared to other features.

Improvement

XGBoost performed well on this classification problem. We can further improve this by using GridSearchCV for parameter tuning to save time. Some advanced NLP techniques can be explored to extract more useful information from text during pre-processing.

Given more data, Deep Learning techniques can be used.