Machine Learning Engineer Nanodegree
Capstone Project Report

I. Definition

Proposal
https://github.com/zhoux0130/capstone-project/blob/main/proposal.pdf

The Background
Since I want to know how to apply ML in insurance, I searched the Competitions in the Kaggle with keyword "insurance", I find this topic _"Allstate Claims Severity".(https://www.kaggle.com/c/allstate-claims-severity)

The Problem Domain and Statement
My motivation is to use ML to reduce redundant tasks in the insurance field, maybe the customer can be provided with services more quickly. The Allstate can also benefit from this point.

This project wants to create an ML model to predict claims severity. They gave us the train data with more than 130 features to predict severity. Since we want to predict a continuous target variable (loss) with many categorical features, I define this problem as supervised learning and regression problem.

Datasets and Inputs

This project contains 2 csv files. They are:

1. train.csv and test.csv features:
    - id: the index of a training set data
    - cat1 to cat116: category variables(The company will not publish the customer's privacy information, so all column names are not provided.)
    - Cont1 to cont14: continuous variables
    - Loss(The target variable): the amount which the company pay for the customer.
2. In train.csv:
    a) 188318 rows
    b) 132 columns
3. In test.csv:
    a) 125546 rows
    b) 131 columns(the test.csv don't have the loss column)

https://www.kaggle.com/c/learnplatform-covid19-impact-on-digital-learning/data

Solution Statement

- Exploratory Data Analysis
  - We may use some plot method to see the features ,the correlation between different features.
- Preprocess Data
  - Since we have some categorical features, we need to convert them into numbers. So the model can use them.
  - There are many features in the train set, it may result in overfitting. So we may have to reduce the features by using PCA.
- Choose and Train Model
  - First we can use linear regression as the base model
  - We may also use XGBoost
  - To use Grid Search method test hyper parameters

Evaluation metrics

The prediction can be evaluated in several ways. Since the problem is regression type,we can use mean absolute error(MAE), mean squared error(MSE), mean squared log error, etc.
As the competition official evaluation is done by Kaggle using mean absolute error, we will use MAE as evaluation.

Mean Absolute Error

$$\mathrm{MAE} = \frac{1}{n}\sum_{j=1}^{n} |y_j - \hat{y}_j|$$

II. Analysis

Data Exploration and Exploratory Visualization

This content is done in file EDA_1.ipynb.
First we will see how the dataset looks like. They are the first 5 rows in the dataset.

```
   id cat1 cat2 cat3 cat4 cat5 cat6 cat7 cat8 cat9 cat10 cat11 cat12 cat13  \
0   1    A    B    A    B    A    A    A    A    B     A     B     A     A
1   2    A    B    A    A    A    A    A    A    B     B     A     A     A
2   5    A    B    A    A    B    A    A    A    B     B     B     B     B
3  10    B    B    A    B    A    A    A    A    B     A     A     A     A
4  11    A    B    A    B    A    A    A    A    B     B     A     B     A

  cat14 cat15 cat16 cat17 cat18 cat19 cat20 cat21 cat22 cat23 cat24 cat25  \
0     A     A     A     A     A     A     A     A     A     B     A     A
1     A     A     A     A     A     A     A     A     A     A     A     A
2     A     A     A     A     A     A     A     A     A     A     A     A
3     A     A     A     A     A     A     A     A     A     B     A     A
4     A     A     A     A     A     A     A     A     A     B     A     A

  cat26 cat27 cat28 cat29 cat30 cat31 cat32 cat33 cat34 cat35 cat36 cat37  \
0     A     A     A     A     A     A     A     A     A     A     A     A
1     A     A     A     A     A     A     A     A     A     A     A     A
2     A     A     A     A     A     A     A     A     A     A     B     A
3     A     A     A     A     A     A     A     A     A     A     A     A
4     A     A     A     A     A     A     A     A     A     A     A     A

  cat38 cat39 cat40 cat41 cat42 cat43 cat44 cat45 cat46 cat47 cat48 cat49  \
0     A     A     A     A     A     A     A     A     A     A     A     A
1     A     A     A     A     A     A     A     A     A     A     A     A
2     A     A     A     A     A     A     A     A     A     A     A     A
3     A     A     A     A     A     A     A     A     A     A     A     A
4     A     A     A     A     A     A     A     A     A     A     A     A

  cat50 cat51 cat52 cat53 cat54 cat55 cat56 cat57 cat58 cat59 cat60 cat61  \
0     A     A     A     A     A     A     A     A     A     A     A     A
1     A     A     A     A     A     A     A     A     A     A     A     A
2     A     A     A     A     A     A     A     A     A     A     A     A
3     A     A     A     A     A     A     A     A     A     A     A     A
4     A     A     A     A     A     A     A     A     A     A     A     A

  cat62 cat63 cat64 cat65 cat66 cat67 cat68 cat69 cat70 cat71 cat72 cat73  \
0     A     A     A     A     A     A     A     A     A     A     A     A
1     A     A     A     A     A     A     A     A     A     A     A     A
2     A     A     A     A     A     A     A     A     A     A     A     A
3     A     A     A     A     A     A     A     A     A     A     A     B
4     A     A     A     A     A     A     A     A     A     A     B     A

  cat74 cat75 cat76 cat77 cat78 cat79 cat80 cat81 cat82 cat83 cat84 cat85  \
0     A     B     A     D     B     B     D     D     B     D     C     B
1     A     A     A     D     B     B     D     D     A     B     C     B
2     A     A     A     D     B     B     B     D     B     D     C     B
3     A     A     A     D     B     B     D     D     D     B     C     B
4     A     A     A     D     B     D     B     D     B     B     C     B

  cat86 cat87 cat88 cat89 cat90 cat91 cat92 cat93 cat94 cat95 cat96 cat97  \
0     D     B     A     A     A     A     A     D     B     C     E     A
1     D     B     A     A     A     A     A     D     D     C     E     E
2     B     B     A     A     A     A     A     D     D     C     E     E
3     D     B     A     A     A     A     A     D     D     C     E     E
4     B     C     A     A     A     B     H     D     B     D     E     E

  cat98 cat99 cat100 cat101 cat102 cat103 cat104 cat105 cat106 cat107 cat108  \
0     C     T      B      G      A      A      I      E      G      J      G
1     D     T      L      F      A      A      E      E      I      K      K
2     A     D      L      O      A      B      E      F      H      F      A
3     D     T      I      D      A      A      E      E      I      K      K
4     A     P      F      J      A      A      D      E      K      G      B


  cat109 cat110 cat111 cat112 cat113 cat114 cat115 cat116     cont1     cont2  \
0     BU     BC      C     AS      S      A      O     LB  0.726300  0.245921
1     BI     CQ      A     AV     BM      A      O     DP  0.330514  0.737068
2     AB     DK      A      C     AF      A      I     GK  0.261841  0.358319
3     BI     CS      C      N     AE      A      O     DJ  0.321594  0.555782
4      H      C      C      Y     BM      A      K     CK  0.273204  0.159990

      cont3     cont4     cont5     cont6     cont7    cont8    cont9  \
0  0.187583  0.789639  0.310061  0.718367  0.335060  0.30260  0.67135
1  0.592681  0.614134  0.885834  0.438917  0.436585  0.60087  0.35127
2  0.484196  0.236924  0.397069  0.289648  0.315545  0.27320  0.26076
3  0.527991  0.373816  0.422268  0.440945  0.391128  0.31796  0.32128
4  0.527991  0.473202  0.704268  0.178193  0.247408  0.24564  0.22089

    cont10    cont11    cont12    cont13    cont14     loss
0  0.83510  0.569745  0.594646  0.822493  0.714843  2213.18
1  0.43919  0.338312  0.366307  0.611431  0.304496  1283.60
2  0.32446  0.381398  0.373424  0.195709  0.774425  3005.09
3  0.44467  0.327915  0.321570  0.605077  0.602642   939.85
4  0.21230  0.204687  0.202213  0.246011  0.432606  2763.85
```

We can see the continuous data’s values are already between 0 and 1, so we can use them directly.

	id	cont1	cont2	cont3
count	150000.000000	150000.000000	150000.000000	150000.000000
mean	234490.288887	0.493660	0.507320	0.498990
std	134937.378713	0.187537	0.207229	0.202252
min	1.000000	0.000016	0.001149	0.002634
25%	117537.750000	0.346090	0.358319	0.336963
50%	234497.500000	0.475784	0.555782	0.527991
75%	351272.000000	0.623912	0.681761	0.634224
max	467728.000000	0.984975	0.862654	0.944251

	cont4	cont5	cont6	cont7
count	150000.000000	150000.000000	150000.000000	150000.000000
mean	0.491802	0.487722	0.490615	0.484894
std	0.211373	0.209136	0.205168	0.178525
min	0.176921	0.281143	0.012683	0.069503
25%	0.327354	0.281143	0.335580	0.350175
50%	0.452887	0.422268	0.440945	0.438285
75%	0.652072	0.643315	0.653958	0.590687
max	0.952482	0.983674	0.997162	1.000000

	cont8	cont9	cont10	cont11
count	150000.000000	150000.000000	150000.000000	150000.000000
mean	0.485975	0.485215	0.497761	0.493302
std	0.199114	0.181607	0.185666	0.209816
min	0.236880	0.000080	0.000000	0.035321
25%	0.312800	0.358970	0.364580	0.310961
50%	0.441060	0.437310	0.461190	0.457203
75%	0.623580	0.558550	0.614590	0.678924
max	0.980200	0.993790	0.994980	0.998742

	cont12	cont13	cont14	loss
count	150000.000000	150000.000000	150000.000000	150000.000000
mean	0.492966	0.492626	0.496251	3040.378682
std	0.209489	0.212733	0.222599	2917.478617
min	0.036232	0.000228	0.179722	0.670000
25%	0.308395	0.315758	0.294772	1202.187500
50%	0.462286	0.363547	0.409813	2115.875000
75%	0.675759	0.689974	0.724733	3869.207500
max	0.998484	0.988494	0.844848	121012.250000

We check the skewness of continuous values. We can see the loss value is positively skewed and needs to be rectified.

id	-0.004008
cont1	0.517909
cont2	-0.312079
cont3	-0.010250
cont4	0.415957
cont5	0.680679
cont6	0.464061
cont7	0.828456
cont8	0.679399
cont9	1.074892
cont10	0.356928
cont11	0.282640
cont12	0.293526
cont13	0.385175
cont14	0.243783
loss	3.901837

Next, we see the correlation between different features, we know the top 5 features have close correlation, we could apply dimensionality reduction method like PCA.

```
cont11 and cont12 = 0.99
cont1 and cont9 = 0.93
cont6 and cont10 = 0.88
cont6 and cont13 = 0.81
cont1 and cont10 = 0.81
cont6 and cont9 = 0.80
cont9 and cont10 = 0.79
cont6 and cont12 = 0.79
cont6 and cont11 = 0.77
cont1 and cont6 = 0.76
cont7 and cont11 = 0.75
cont7 and cont12 = 0.74
cont10 and cont12 = 0.71
cont10 and cont13 = 0.71
cont10 and cont11 = 0.70
cont6 and cont7 = 0.66
cont9 and cont13 = 0.64
cont9 and cont12 = 0.63
cont1 and cont12 = 0.61
cont9 and cont11 = 0.61
cont1 and cont11 = 0.60
cont1 and cont13 = 0.53
cont4 and cont8 = 0.53
```

We can also see the value distribution with the categorical features.(The visualization plot can check the EDA_1.ipynb file)
Cat1 to 72 have only two labels like A and B.

Cat73 to 108 have more than tow labels, but they don't have too many.

Cat109 to 116 have many labels.

Algorithms and Techniques

Since we want to predict a continuous target variable (loss) with many categorical features, I can use the linear regression to solve this problem.

Linear Regression

We can fit a curved line passing through feature points, and use it to predict the loss value. But in this problem, we have almost 119 features, it's too many for the linear regression. We will use this algorithms as base classifier and get a base loss value, and we will try to minimize the loss value with other models.

XGBoost

XGBoost is an implementation of gradient boosted decision trees which is for speed and performance. The decision tree take several weak features and combine them to get a strong model. Since I have this project mostly running on my laptop, I like the XGBoost execution speed and model performance.

Benchmark Model

We can see leaderboard in the Kaggle project page, the Top solution's score is

1109.70772 MAE.

Then we can use part of training data as testing data to see the linear regression model's

accuracy as base. Then we compare next model to see how it works. We will choose a better model to run the test.csv, and upload the submission file to check the score.

III. Methodology

Data Preprocessing

As we just say , loss column is positively skewed. We will take log of the loss + shift. Shift is another hyper-parameter. It gives better performance. I found it from the discussion(https://www.kaggle.com/c/allstate-claims-severity/discussion/24611)

After log the loss value, it is normalized.

Since there are 114 columns which are categorical features, we will make them numbers. Also I use 150000 entries as train data and the other 38318 entries as test data from train.csv.

Implementation

There are my steps with linear regression algorithms:

1. We import linear regressor from sklearn and also mean absolute error.
2. We train the model
3. We predict the results of the test set
   Since we transform target value into log(loss + shift), we have to convert the predict result back.
4. We calculate the MAE between the predict values and actual values.

Here are my steps to implement the XGBoost model.
1. We preprocess the data and divide it into training and testing data.
2. We implement the XGBoost model.

   I have to notice the tuning processing. Since I have used out my AWS account's

budget, I can't tune the hyper-parameters on AWS, I have tuned it manually.

Refinement

We got a base result(1267.48) with linear regression algorithms, and obtained result(1149.75) with naive XGBoost algorithms, which is better than the base result.

Next we need to find the optimal parameters for the model.Since I have used out my AWS account's budget, I can't tune the hyper-parameters on AWS, I have tuned it manually.

The first two parameters which I use are max_depth and min_child_weight. And I run the program on my friend's cloud computer for once. Finally, I got the better result with the parameters as follow:
Max_depth = 6 and min_child_weight = 8

At last, we use these parameters and reduce the learning rate to 0.01.

IV. Results

Model Evaluation and Validation

At last, we got the result 1132.3 by tuning the parameters. It's better than linear and naive XGBoost algorithms.

Then I check the kaggle score, and submit the file. Finally we got the result 1120.234.

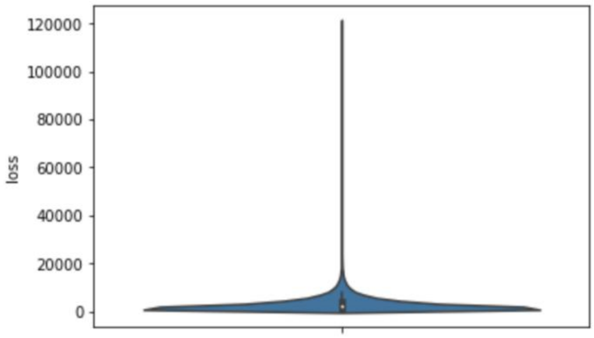
Justification

First the score is better than our base algorithms performance. And the result almost is Rank 500 of 3000(total teams), about first top 20% level. I am satisfied about the result.

V. Conclusion

Free-Form Visualization

We can see the loss value's violin plot , it can be clearly seen that it is skewed.



Reflection

Since all the features have no meanings and I don’t have enough domain knowledge, however for sake of academic purposes, I am satisfied with the result.

Improvement

1. I could use the AWS SageMaker to train the model automatically.
2. PCA could be tired to reduce the features. But we don’t know the features’ meaning, it may bring uncertainty.

References

1. Hands-on Machine Learning with scikit-Learn, Keras & TensorFlow, chapter 2
2. Comparing different metric

https://medium.com/usf-msds/choosing-the-right-metric-for-evaluating-machine-learning-models-part-2-86d5649a5428

3. Tuning XGBoost
   https://www.kaggle.com/c/allstate-claims-severity/discussion/24611