

Project Report 1

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In this project, we implement two basic machine learning models: logistic regression and naive bayes. These models are tested upon four classification datasets: Ionosphere Dataset, Iris Dataset, Car Evaluation Dataset and Adult Dataset. These datasets contain various types of features: both continuous and discrete. In the pre-processing phase, we first discretize all the continuous features, handling the missing values and values out of range. In the experiment phase, apart from reporting evaluation metrics upon various models with different datasets, we further investigate the influence of different learning rates, different stopping criteria, hyper-parameter tuning, feature selection and dataset selection.

1 Introduction

Classification tasks is one of the most common and important task in machine learning community. Given certain features, classification task is to categorize which class is most likely to be. In this project, we implement two basic machine learning models: logistic regression and naive bayes, and test their performance upone four datasets: Ionosphere Dataset¹, Adult Dataset², Iris Dataset³ and Car Evaluation Dataset⁴. All the features are discretized during the pre-processing phase. We further investigate the influence of different training techniques, such as hyper-parameter tuning and feature selections, upon the performance of the models.

2 Datasets

The targets of all these four datasets are categorical classification (including binary classification). We exam four datasets to find that no missing values exist. We use *replace* function in *pandas* module to process all the target values into categorical count value. We will briefly describe the specific features and then introduce how to extract/process the features.

Ionosphere Dataset

Ionosphere dataset contains 34 radar data (real values between -1 and 1) with 351 rows[1]. We find their distribution with respect to the "good" or "bad" target, which is reflected in Figure 1. We then remove radar 1 feature which is always 0. We can see that good class and bad class have quite distinct patterns in the antennas power value, which is essential in the following classification. We also fill between the intervals of good-class feature distribution to find that such surface is quite similar to the auto-correlated signals. Therefore, we use Principal Component Analysis (PCA) to reduce the dimensions from 34 into 10 to learn the low-rank representation for more efficient and powerful training.

¹<https://archive.ics.uci.edu/ml/datasets/ionosphere>

²<https://archive.ics.uci.edu/ml/datasets/Adult>

³<https://archive.ics.uci.edu/ml/datasets/Iris>

⁴<https://archive.ics.uci.edu/ml/datasets/Car+Evaluation>

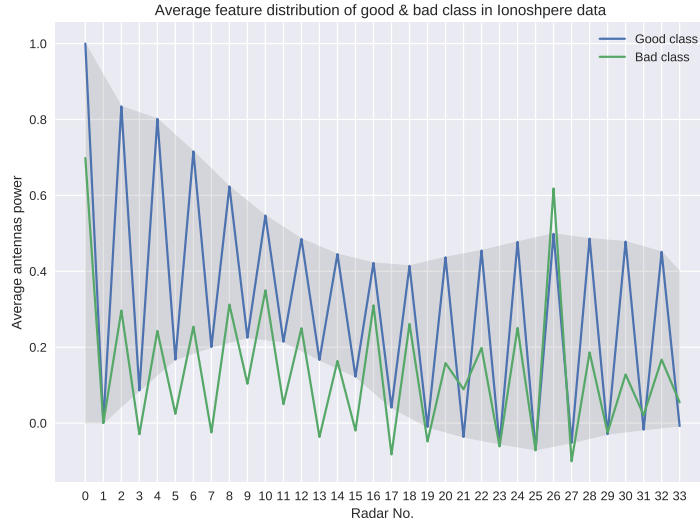


Figure 1: Distribution of average numerical features given "good" or "bad" class in ionosphere dataset

Adult Dataset

Adult dataset aims to predict whether income exceeds \$50K/yr based on census data[2]. There are 32561 records and 14 features included with datatypes of continuous count values, continuous real values and categorical/binary values. We min-max normalize the continuous values (both count and real), discretize normalized real values into 10 categories and leave everything else untouched.

Iris Dataset

There are 4 continuous real values attribute with 1 decimal precision, whose basic statistic information are listed in Figure 2 and Table 1, where *sl, sw, pw, pl* stand for *sepal length*, *sepal width*, *petal width*, *petal length* [3]. Linear correlation between features can be found, e.g. petal length & petal width and petal length & sepal length. We also min-max, normalize and then discretize the normed real values.

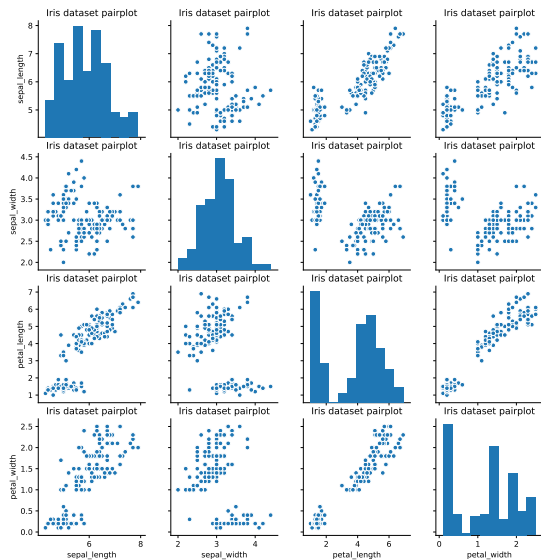


Figure 2: Pairplot of iris data features

	sl	sw	pl	pw
count	150	150	150	150
mean	5.84	3.05	3.75	1.19
std	0.82	0.43	1.76	0.76
min	4.3	2.0	1.0	0.1
25%	5.1	2.8	1.6	0.3
50%	5.8	3.0	4.3	1.3
75%	6.4	3.3	5.1	1.8
max	7.9	4.4	6.9	2.5

Table 1: Iris data description

Car Evaluation Dataset

In Car Evaluation Dataset, we use 1728 records from 6 categorical features of cars, e.g. price, door number and capacity, to predict the safety level of the cars [4]. This dataset is quite straight-

forward, we only transform the raw data into categorical features to predict the categorical safety level.

3 Results

Accuracy comparison on four datasets

From Table 2, for accuracy of each model, we find that our implemented logistic regression model can work well on small datasets (iris and ionosphere datasets) but worse in larger dataset (car and adult datasets) compared with sklearn model. In the contrary, naive bayes work well on large data set but worse in small dataset.

	iris	car	adult	ionosphere
logistic regression(ours)	0.75	0.65	0.66	0.80
logistic regression(sklearn)	0.93	0.87	0.82	0.82
naive bayes(ours)	0.34	0.69	0.76	0.67
naive bayes(sklearn)	0.74	0.69	0.75	0.81

Table 2: Accuracy of our implemented model in four datasets comparing to sklearn module

Furthermore, we compare the different evaluation metrics for binary classification, where ionosphere dataset and adult dataset are selected. Details can be found in Table 3, where **o** stands for our model and **s** for results after running *sklearn* module. We found that our model have lower precision and recall on class 1 for large data set (car data), which can explain why the model fail to show the performance like sklearn model. We plan to investigate more in the characteristic of the features in large dataset.

	ionosphere/adult		dataset				
	precision(o)	precision(s)	recall(o)	recall(s)	f1(o)	f1(s)	support
class 0	1.00/0.93	0.90/0.83	0.48/0.49	0.48/0.95	0.65/0.64	0.86/0.89	33/4937
class 1	0.69/0.35	0.85/0.71	1.00/0.88	1.00/0.39	0.81/0.51	0.88/0.51	37/1575
macro avg	0.84/0.64	0.88/0.77	0.74/0.68	0.74/0.67	0.73/0.57	0.87/0.70	70/6512
weighted avg	0.83/0.79	0.87/0.80	0.76/0.58	0.76/0.81	0.74/0.61	0.87/0.79	70/6512

Table 3: Different evaluation metrics of our implemented model in binary-target datasets comparing to sklearn module

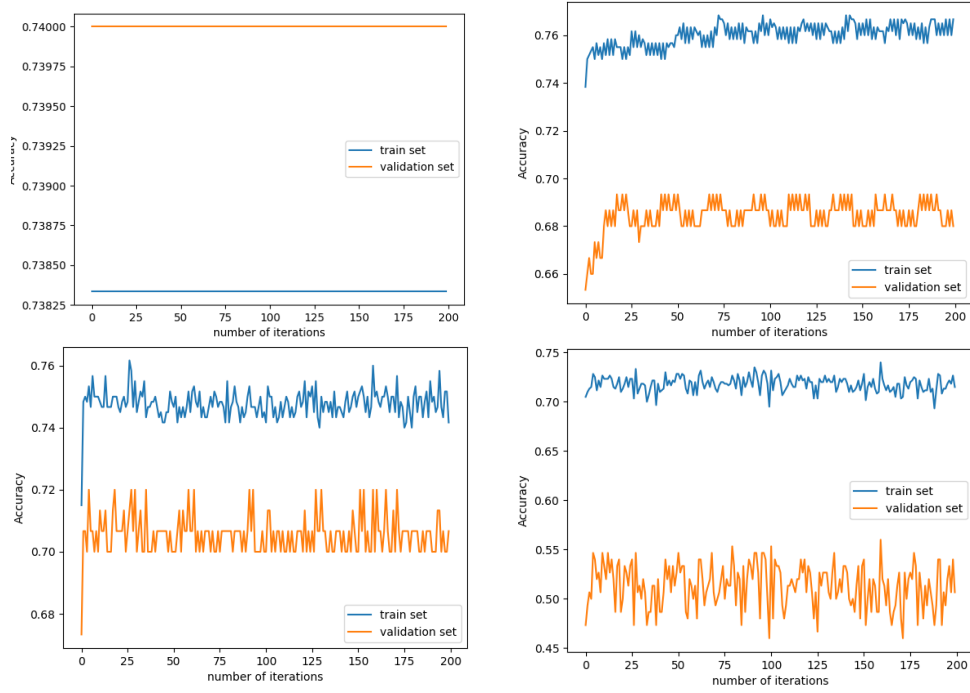


Figure 3: Learning rate test, from left top to right top, from left bottom to right bottom, the learning rates are: 0.001, 0.01, 0.1 and 1

Learning rate test

We mainly test several learning rates with stopping threshold 0.05 in the iris dataset, which is shown in Figure 3. For small learning rate, like 0.0001, the accuracy makes no change during the gradient decent, which means that it converges very slow. When the learning rate is very big such as 1, the accuracy will fluctuate sharply, which means that it will become unstable during gradient descent.

We found the best learning rate in our experiment should be around 0.01. so we did hyper-parameter search experiments around 0.01 in a small range, which is in Figure 4. We can find the best learning rate for iris should be xx, besides we also search the learning rate in ionosphere data set, the best learning rate should be xx according to our experiment, for car data set it should be, for adult dataset it should be .

Stopping criteria for logistic regression

We also investigate the stopping criteria on four datasets. The stopping criteria is considered as a threshold for change in the value of cost function. We plot the accuracy on four different datasets. In our results, we find there are not much influence on accuracy for car and adult datasets because these two datasets are very big, our model may need to run max iteration to meet the optimal solution. We find that for iris and ionosphere datasets, there will be optimal criteria, which are 0.15 and 0.14 respectively.

Accuracy as a function of the size of dataset

From Figure 5 we can find that accuracy increases when sample size is roughly less than 200. However, the accuracy becomes stable even the sample size continues growing.

Dimension reduction comparison

Because ionosphere has strong auto-correlated, we use PCA to reduce the dimensions for better training results, which can be reflected in Figure 6. It can be found that accuracy on both training and validation sets perform better if PCA is applied. By using PCA for dimension reduction, we can select a good subset of features.

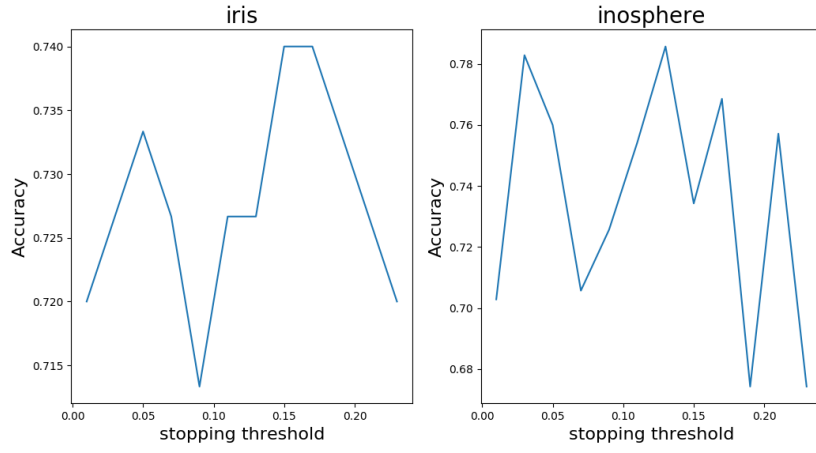


Figure 4: Best stopping criterion for Ionosphere Dataset and Iris Dataset given optimal learning rate

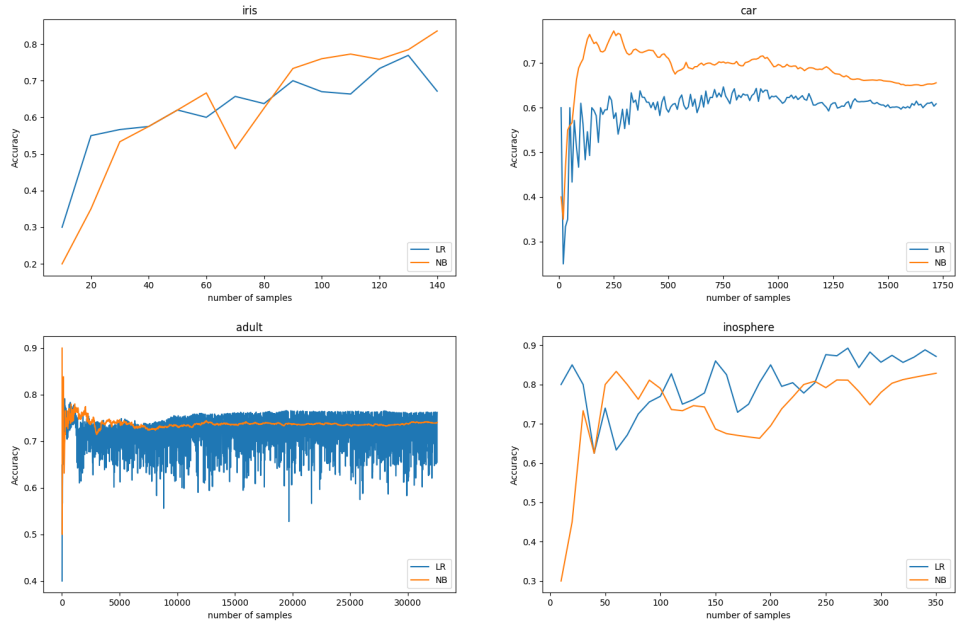


Figure 5: Impact of the training sample size on the accuracy

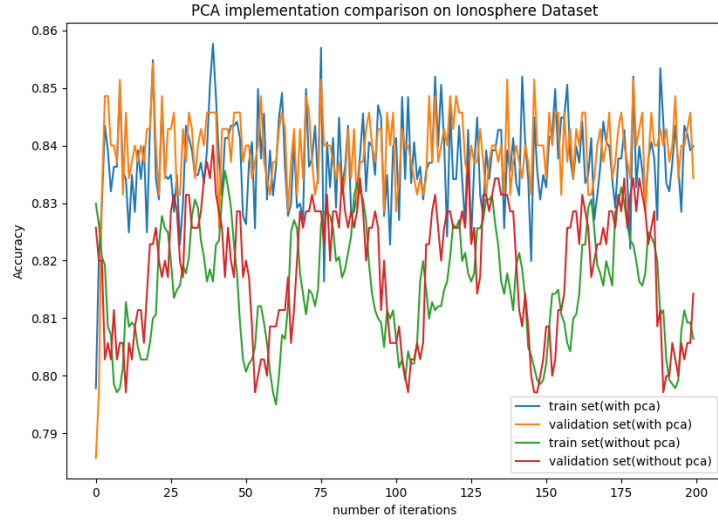


Figure 6: Training and validation accuracy comparison before and after using PCA

4 Discussion and Conclusion

5 Statement of Contributions

- Dingyi Zhunag: Data preprocessing, data analysis and report forming.
- Fuyuan Lyu: Model implementation and report writing.
- Tianyu Shi: Running experiment, data visualization and data analysis.

References

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- [2] Ron Kohavi. Scaling up the accuracy of naive-bayes classifiers: A decision-tree hybrid. In *Kdd*, volume 96, pages 202–207, 1996.
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- [4] Marko Bohanec and Vladislav Rajkovic. Knowledge acquisition and explanation for multi-attribute decision making. In *8th Intl Workshop on Expert Systems and their Applications*, pages 59–78, 1988.