Advances in Social Science, Education and Humanities Research, volume 653
**Proceedings of the 2022 International Conference on Social Sciences and Humanities and Arts (SSHA 2022)**

# Reducing PEG Values by Comparing and Combining Various Approaches

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**ABSTRACT**
This research aims to compare different approaches and combine the best approaches to reduce the Probability of Generalization Error (PEG) values of spoken classification. The size of training set is expanded by doubling specific rows for the training database to compare regularization and choose the best one for use and the Bagging method, Kfold method and Restarts method are compared to find the best one, which is combined with the regularization through the new database. The parameters are changed to combine the regularization with the method in accordance with the PEG values, and the best parameters are chosen which are also the best combination of the regularization with the method. Therefore, the best model of the best combination is picked out. Finally, the lowest PEG value is produced by using committee vote.

***Keywords:*** *PEG values, database, regularization methods, best parameters, best combination.*

## 1. INTRODUCTION

Machine learning, speech recognition included, is becoming more and more popular and essential for not only for modern society but also in the future. In this paper, the researcher also focus on classifying spoken digits with Deep Neural Network.

The PEG values are relatively higher in the recent work of using the DNN to classify the spoken databases which contain rows labeled with numbers from 0 to 9, while I am interested in using different approached to try to reduce the PEG values. As the PEG values of the Chinese database is relative higher, I decide to mainly focus on reducing PEG values of Chinese database.

The research focuses on getting as small as possible PEG value based on the original database. The number of training samples is increased by doubling specific rows and the data augmentation techniques which include noise and regularization augmentation is used in the train data set of this work. Besides, with deep learning neural (DNN) network, I use three different methods and pick out one which can get the lowest PEG values. After that, I combine the steps together to get best models which can produce the lower PEG values and use the voting method to give me the final lowest PEG value.

Section 2 describes the process of comparing and choosing the regularization and method which can produce the lower Probability of Generalization Error (PEG) values.

Section 3 describes changing the database by appending rows that are labeled with specific numbers to reduce the PEG values of classification for the Chinese database.

Section 4 describes combining regularization with method, changing the parameters of the combination to pick out the best parameters, and finally, picking out the best models of the best combination, then using committee vote to produce the lowest PEG value.

In general, the PEG values are reduced by about 77% compared to the original DNN with the original database. Finally, conclusions are drawn in Section 5.

# 2. COMPARING AND PICKING OUT THE REGULARIZATION AND METHOD

## *2.1 Comparing and Picking out the regularization*

### *2.1.1 Comparing the regularization*

Using regularization [1] in the DNN to classify the original database, comparing the PEG values and choosing the best regularization to use in the next step.

The chart below contains the data characteristics of the PEG values that were produced by different regularization.

**Table 1：** PEG values produced by regularization with Chinese database

| Chinese database | Min PEG | Lower Box PEG | Median PEG | Upper Box PEG | Max PEG |
|---|---|---|---|---|---|
| No reg | 0.1552 | 0.1561 | 0.1651 | 0.1832 | 0.1858 |
| Weight size | 0.1406 | 0.1535 | 0.1690 | 0.1832 | 0.2322 |
| Dropout | 0.1367 | 0.1445 | 0.1503 | 0.1665 | 0.1781 |
| Adding noise | 0.1290 | 0.1329 | 0.1374 | 0.15096 | 0.1561 |
| Early stopping | 0.169 | 0.2 | 0.2296 | 0.24 | 0.2645 |

**Table 2：** PEG values produced by regularization with English database

| English database | Min PEG | Lower Box PEG | Median PEG | Upper Box PEG | Max PEG |
|---|---|---|---|---|---|
| No reg | 0.1329 | 0.1509 | 0.1535 | 0.1561 | 0.16 |
| Weight size | 0.1303 | 0.1367 | 0.1477 | 0.1574 | 0.1741 |
| Dropout | 0.1161 | 0.12 | 0.1354 | 0.1496 | 0.1548 |
| Adding noise | 0.9806 | 0.1174 | 0.1251 | 0.1354 | 0.1535 |
| Early stopping | 0.1690 | 0.1896 | 0.2077 | 0.2219 | 0.2477 |

### *2.1.2 Picking out the regularization*

The chart 1 shows that Adding noise [2] and Drop out [3] can produce lower PEG values in the Chinese database classification.

The chart 2 shows that Adding noise [2] and Drop out [3] can also produce lower PEG values in the English database classification.

Therefore pick out Adding noise [2] and Drop out [3] for the next step.

## *2.2 Comparing and Picking out the method*

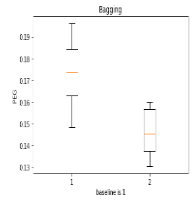
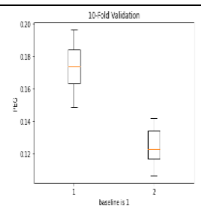
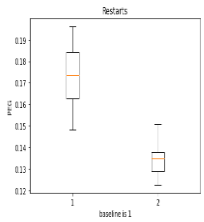
### *2.2.1 Comparing the regularization*

The Kfold [4], Bagging [5] and Restarts methods are used to classify the original database, compare the PEG values and so as to choose the best one for the next step.

The chart below contains the data characteristics of the PEG values that were produced by different methods and the box plot of the PEG values. The plot also compares the PEG values of baseline which only uses DNN to classify the database with the PEG values of the method.

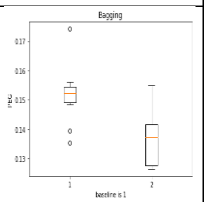
Nlayers = 2 Nnodes = 50 Nepochs = 80

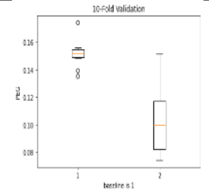
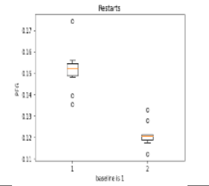
**Table 3:** PEG values and plots produced by methods with Chinese database

| Chinese database | Median PEG | Mean PEG | SD | PLOT BOX |
|---|---|---|---|---|
| Bagging | 0.1452 | 0.1457 | 0.0105 |  |
| K-fold | 0.1226 | 0.1239 | 0.011 |  |
| Restart | 0.1348 | 0.1341 | 0.0077 |  |

Nlayers = 2 Nnodes = 50 Nepochs = 80

**Table 4:** PEG values produced by regularization with English database

| English database | Median PEG | Mean PEG | SD | PLOT BOX |
|---|---|---|---|---|
| Bagging | 0.1374 | 0.1365 | 0.0088 |  |

| | | | | |
|---|---|---|---|---|
| K-fold | 0.1000 | 0.1026 | 0.023 |  |
| Restart | 0.1206 | 0.1212 | 0.0054 |  |

### *2.2.2 Picking out the method*

The chart 3 shows that Kfold [4] can produce lower PEG values in the Chinese database classification, and all methods can produce lower PEG values than the baseline.

The chart 4 shows that Kfold [4] can also produce lower PEG values in the English database classification, and all methods can produce lower PEG values than the baseline.

Therefore pick out Kfold [4] for the next step.

## 3. DATABASE PROCESSING

### *3.1 Finding the problems*

The DNN is used to classify the original Chinese database which contains 3100 rows, 310 rows for each number from 0 to 9, and the confusion matrix (CM) is printed to see where the problems are.

The CM is:

```
[[38  4  1  0  1  0  5  2  0  0]
 [ 1 37  0  1  1  1  0  4  0  0]
 [ 0  0 46  2  0  0  0  0  1  0]
 [ 0  2  1 56  4  0  0  0  0  0]
 [ 0  0  1  1 51  2  0  1  0  1]
 [ 0  1  0  0  0 65  1  0  0  3]
 [ 1  0  0  0  0  0 56  0  0  8]
 [ 2 16  0  0  0  1  0 45  1  0]
 [ 0  0  7  7  0  0  0  0 55  1]
 [ 2  0  0  0  0  3  1  0  1 58]]
```

In the CM, many 7s are classified wrongly as 1. As the pronunciations of them are similar, there might be the similar waveforms that caused the higher PEG values. Then run the show spectrum program to see the spectrum [6] of 1 and 7.

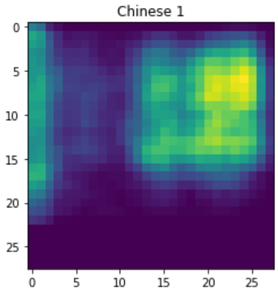



**Figure 1** spectrum of Chinese 1

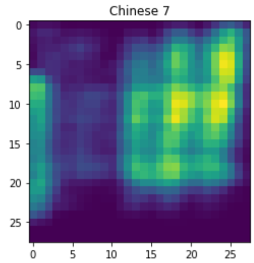



**Figure 2** spectrum of Chinese 7

The two pictures of 1 and 7 are actually similar. If the program has more data about 1 and 7 to train, the accuracy of the classification might be improved.

### *3.2 Double the rows*

### *3.2.1 Bring out the rows*

So I wrote a function to bring out the rows which are labeled with 1and 7 in the original database, the picture below is the function.


**Figure 3** the function that bring out the rows labeled with 1 and 7

First, load the original database, and then sort out the rows of the database according to the label numbers. After that all rows that are labeled with the same number are put together. The start Index is one that the label number first appeared, and the end Index is the label number last appeared. Then using the two indexes to bring out specific rows which are labeled with same number.

### *3.2.2 Append the rows to the database and compare with the original database*

Appending these rows to the original database, the using the new database to train in the DNN. The plots below are produced by DNN with the original database and the new database.

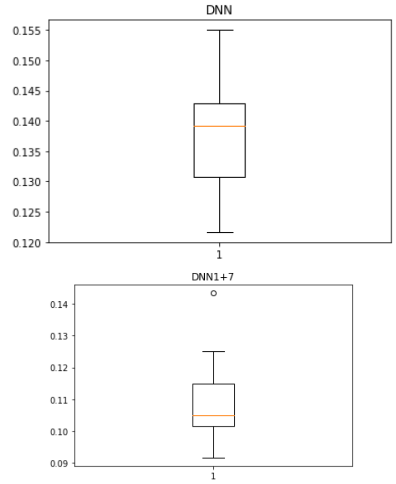



**Figure 4** the plot of PEG values of the original database and the new database

The PEG values of the new database are lower than that of the original database. From the plots, the researcher can know doubling the specific rows in the database can really help to reduce the PEG values.

### *3.3 Append more rows and compare the PEG values*

There are also other numbers that have similar spectrogram [6], such as 3 and 4, 6 and 9.

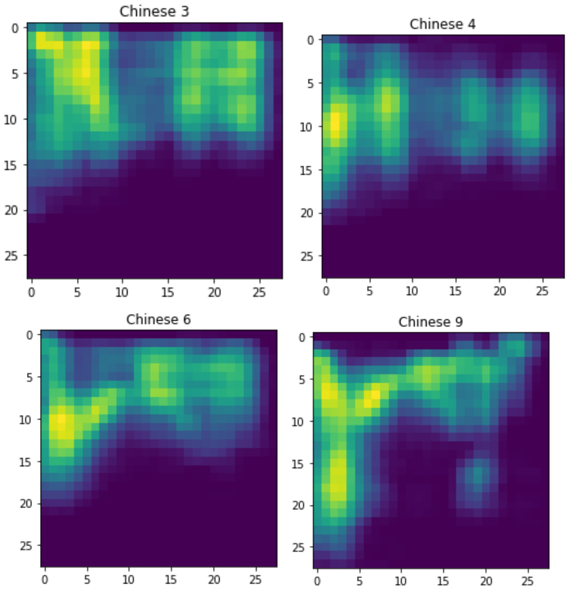



**Figure 5** the spectrum of Chinese 3 and 4, 6 and 9

Bring the rows that are labeled with the numbers, appending the rows to the new database which already had more rows of 1 and 7. There are two steps, and the first one is to append the rows of 3 and 4, and the second is to append the rows of 6 and 9. Use DNN to classify the database, and print the plots.

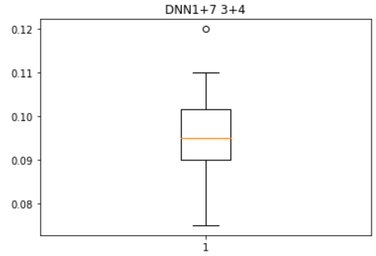



**Figure 6** the plot of PEG values of the database which contains doubled 1,7,3,4

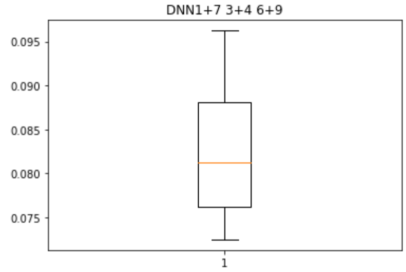



**Figure 7** the plot of PEG values of the database which contains doubled 1,7,3,4,6,9

From the plots, the researcher can see that after appending each couple of the numbers, the PEG values reduced. And there are no numbers that have the similar spectrogram and waveforms, so the PEG values cannot reduce any more by changing the database.

With the new database, the PEG values may reduce further more by combining the regularization and Kfold.

## 4. COMBINING REGULARIZATION WITH METHOD AND CHOOSING THE PARAMETERS

### *4.1 Find an appropriate number of restarts*

First of all, I wrote a loop to determine an appropriate number of restarts for adding noise and drop out.

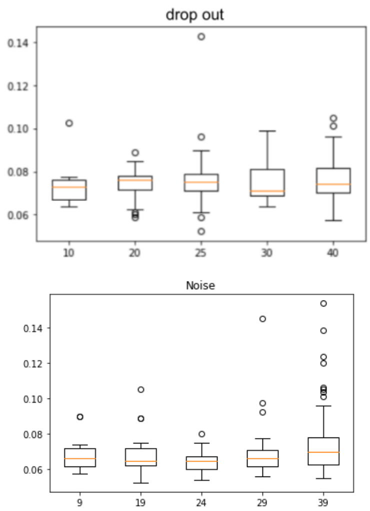



**Figure 8** the plot of PEG values of dropping out and

adding noise with different restarts

From the plots above, the researcher can see 25 restarts can produce relatively lower PEG values, which doesn't spend much time, therefore 25 restarts are used in the later steps.

## *4.2 Combine Adding noise and Drop out with Kfold to get the lowest PEG value*

### *4.2.1 Combine Adding noise with Kfold and changing the SD values*

The plots above are used to compare the combination of Kfold and adding noise only. It is obvious that the combination can reduce the PEG values more effectively. The plots also change the SD values of the noise from 0 to 0.6 to see the trend of the PEG values, in order to narrow down the choices of the best SD values.

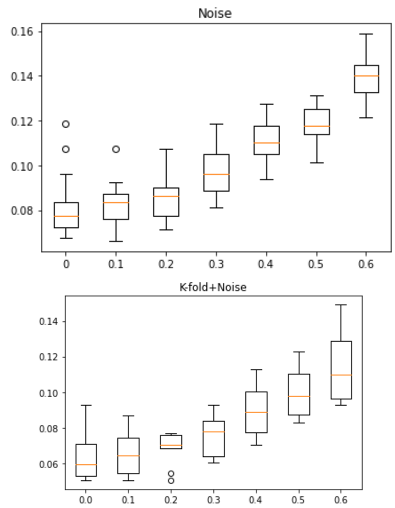



**Figure 9** the plot of PEG values of adding noise and kfold+adding noise with different SD values

### *4.2.2 Pick out the best SD values*

From Figure 9, the researcher can see that the best SD values are most likely around 0 to 0.2, so shrinking the range of SD values to make it around 0 to 0.2 so as to find out the best SD values.

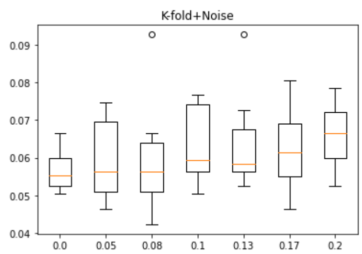



**Figure** 10 the plot of PEG values of kfold+adding noise with different SD values

According to Figure 10, the best SD values are 0.05, 0.08 and 0.17. Then these values are used in combined with adding noise with drop out in the Kfold to produce the best models.

### *4.2.3 Combine Drop out with Kfold and changing the p values*

The plots above are used to compare the combination of Kfold and Drop out with single adding noise. It is obvious that the combination can reduce the PEG values more effectively. The plots also change the p values of the noise from 0 to 0.6 to see the trend of the PEG value in order to narrow down the choices of the best P values.

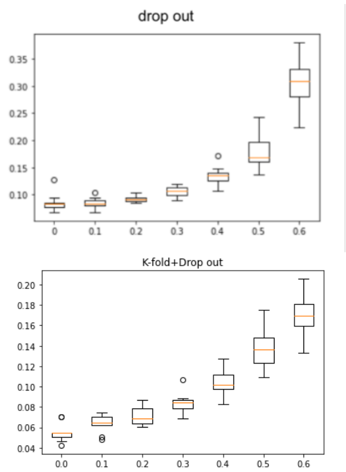



**Figure 11** the plot of PEG values of dropping out and kfold+ dropping out with different p values

### *4.2.4 Pick out the best p values*

From Figure 11, the researcher can see that the best SD values are most likely around 0 to 0.2, so that the researcher shrink the range of SD values to make it from 0 to 0.2 so as to find out the best SD values.

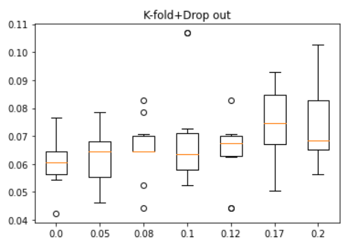



**Figure 12** the values are used in combined with adding noise with drop out in the Kfold to produce the best models.

According to Figure 12, the best p values are 0.05, 0.08 and 0.12. Then these values are used in combined with adding noise with drop out in the Kfold to produce the best models.

### *4.3 Put Adding noise and Drop out together in the Kfold with the best parameters*

#### *4.3.1 Use the SD values and P values to produce the lowest PEG values and pick out the best combination.*

Then put both adding noise and drop out in the Kfold. First, make p=0.05, changing the SD values which are 0.05, 0.08 and 0.17. Second, make p=0.08, changing the SD values which are 0.05, 0.08 and 0.17.Third, make p=0.12, changing the SD values which are 0.05, 0.08 and 0.17.

Compare the box plots to see which combination is the best one that can produce the lowest PEG values.

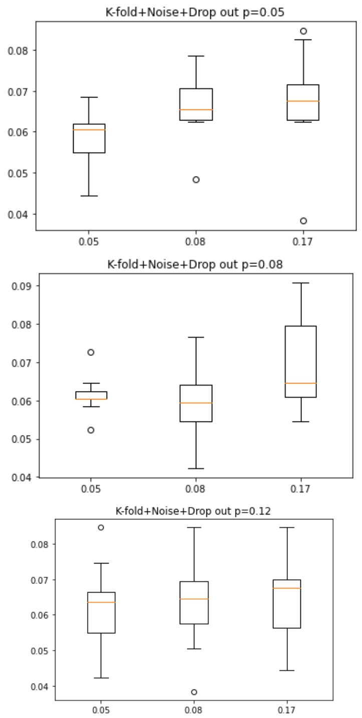



**Figure 13** the plot of PEG values of kfold+dropping out+adding noise with the best p values and SD values

By comparing Figure 13 with Figure 12 and Figure 10, Adding noise and Drop out Kfold have more models that can produce lower PEG values. And when p=0.08, SD=0.08, the PEG values are relatively lower than others, so picking the best three models of this combination and use them in the committee vote to produce the lowest PEG value.

#### *4.3.2 Use the best models of the best combination in the committee vote*

Pick out the best three models of the best combination and using them in the committee vote to produce the lowest PEG value.

```
Enter Chinese (C) or English (E)  C
C Kfold Committee of 3 votes gives PEG= 0.0271
```

The lowest PEG value = 0.0271

## 5. CONCLUSION

I have presented a study of the performance of two hidden layers neural network and gives the practical methods to improve the accuracy of neural networks.

In this study, I focus on comparing and combining the regularization and the three methods to choose some of them to use and appending specific rows of the Chinese database. Furthermore, the best models are chosen to produce the lowest PEG values. Comparing to the lowest PEG value of the baseline (using DNN to classify the original database), when the final lowest PEG value which equals to 0.0271, the PEG value has reduced by 77.7%.

To conclude, the results of the research support that comparing different approaches and combining better approaches of reducing the PEG values can do a better job than any single approach.

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