Leaf-Classification

Use deep learning to classify the species of leaf automatically.

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- Motivation
- Purpose

Classify the species of leaf automatically?

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- Fitting environment(each model is same)
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Motivation & Purpose

Classify the species of leaf automatically?

There are estimated to be nearly half a million species of plant in the world. Classification of species has been historically problematic and often results in duplicate identifications.

If we can create the classifier to classify the species of leaf automatically,it means we can create the model as botanist through the trained model with dataset of leaf.

My purpose is try building a classifier that uses the provided pre-extracted features.

Date information

Data source

Data description

The data consists approximately 1,584 data of leaf specimens (16 samples each of 99 species) .

Data feature

Feature type

Three sets of features are also provided per image: a shape(shape1~shape 64) contiguous descriptor, an interior texture(texture 1~texture 64) histogram, and a fine-scale margin(margin 1~margin 64) histogram. For each feature, a 64-attribute vector is given per leaf sample.

Data file

File description

- ➢ Train.csv(990 data containing 64 features and corresponding species)
- ➢ Test.csv(594 data containing 64 features and no species)

Data file (ex:Train.csv include 990 data)

Features of leaf

id	species	margin1	margin2	margin3	margin4	margin5	margin6	margin7	margin8	margin9	margin10	margin11	margin12	margin1
1	Acer_Opalus	0.007812	0.023438	0.023438	0.003906	0.011719	0.009766	0.027344	0	0.001953	0.033203	0.013672	0.019531	
2	Pterocarya_Stenopte	0.005859	0	0.03125	0.015625	0.025391	0.001953	0.019531	0	0	0.007812	0.003906	0.027344	
3	Quercus_Hartwissian	0.005859	0.009766	0.019531	0.007812	0.003906	0.005859	0.068359	0	0	0.044922	0.007812	0.011719	
5	Tilia_Tomentosa	0	0.003906	0.023438	0.005859	0.021484	0.019531	0.023438	0	0.013672	0.017578	0.001953	0.019531	
6	Quercus_Variabilis	0.005859	0.003906	0.048828	0.009766	0.013672	0.015625	0.005859	0	0	0.005859	0.001953	0.044922	
8	Magnolia_Salicifoli	0.070312	0.09375	0.033203	0.001953	0	0.15234	0.007812	0	0.003906	0.027344	0.058594	0	
10	Quercus_Canariensi	0.021484	0.03125	0.017578	0.009766	0.001953	0.042969	0.039062	0	0.003906	0.019531	0.035156	0.015625	
11	Quercus_Rubra	0	0	0.037109	0.050781	0.003906	0	0.003906	0	0.048828	0.003906	0.001953	0.005859	
14	Quercus_Brantii	0.005859	0.001953	0.033203	0.015625	0.001953	0	0.023438	0	0	0.021484	0.007812	0.033203	
15	Salix_Fragilis	0	0	0.009766	0.037109	0.072266	0	0	0	0.007812	0.001953	0	0.029297	
17	Zelkova_Serrata	0.019531	0.03125	0.001953	0.005859	0.003906	0.013672	0.033203	0	0.011719	0.042969	0.015625	0.017578	
18	Betula_Austrosinensi	0.001953	0.001953	0.023438	0.025391	0.076172	0	0.029297	0	0.005859	0.015625	0.001953	0.003906	
20	Quercus_Pontica	0.015625	0.011719	0.041016	0.003906	0.023438	0.015625	0.019531	0	0.009766	0.015625	0.003906	0.046875	
21	Quercus_Afares	0.011719	0.011719	0.054688	0.017578	0.007812	0.009766	0.011719	0.007812	0.025391	0.015625	0.027344	0.009766	
22	Quercus_Coccifera	0.011719	0.007812	0.11133	0.027344	0.023438	0.039062	0.013672	0	0.001953	0.013672	0.005859	0.009766	
25	agus_Sylvatica	0.027344	0.025391	0.066406	0.007812	0.003906	0.052734	0.03125	0	0.003906	0.039062	0.003906	0.001953	
26	Phildelphus	0.009766	0.0625	0.033203	0.029297	0.011719	0.044922	0.005859	0	0.009766	0.017578	0.039062	0.001953	
27	Acer_Palmatum	0	0	0.001953	0.029297	0.11133	0	0	0	0.029297	0	0	0	
29	Quercus_Pubescens	0.001953	0	0.015625	0.03125	0.011719	0	0.021484	0.001953	0.005859	0.013672	0.003906	0.015625	
30	Populus_Adenopoda	0.005859	0.027344	0.017578	0.041016	0.007812	0.017578	0.046875	0.001953	0	0.044922	0.001953	0.001953	
3	Quercus_Trojana	0.019531	0.019531	0.064453	0.025391	0.007812	0.005859	0.023438	0	0.005859	0.003906	0.011719	0.021484	
3	Quercus_Variabilis	0.019531	0.029297	0.080078	0.033203	0.025391	0.023438	0.009766	0.005859	0	0.009766	0.021484	0.011719	
3	Alnus_Sieboldiana	0	0.005859	0.023438	0.001953	0.013672	0.001953	0.015625	0	0.003906	0.007812	0.001953	0.019531	
35	Quercus_Ilex	0.029297	0.033203	0.033203	0.021484	0.001953	0.068359	0.037109	0	0.005859	0.080078	0.029297	0.005859	
7	Arundinaria_Simonii	0.001953	0.023438	0.005859	0.029297	0	0	0	0	0.011719	0	0.10742	0	
8	Acer_Platanoids	0.015625	0.03125	0.10156	0.015625	0.005859	0.017578	0	0	0.041016	0.005859	0.015625	0.007812	
0	Quercus_Phillyraeoi	0.027344	0.009766	0.021484	0.042969	0.017578	0.009766	0.037109	0.03125	0.005859	0.037109	0.021484	0.003906	
42	Cornus_Chinensis	0.085938	0.095703	0.007812	0.003906	0	0.14844	0.007812	0	0.007812	0.027344	0.023438	0	
43	Quercus_Phillyraeoi	0.001953	0.003906	0.017578	0.044922	0.041016	0.011719	0.039062	0.013672	0.011719	0.021484	0.011719	0.003906	

Species of leaf

Tip

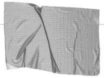
The data source is from Kaggle: https://www.kaggle.com/c/leaf-classification/data

Data file (ex:Test.csv include 594 data)

Features of leaf

id	margin1	margin2	margin3	margin4	margin5	margin6	margin7	margin8	margin9	margin10	margin11	margin12	margin13	mai
4	0.019531	0.009766	0.078125	0.011719	0.003906	0.015625	0.005859	0	0.005859	0.023438	0.005859	0.021484	0.076172	
7	0.007812	0.005859	0.064453	0.009766	0.003906	0.013672	0.007812	0	0.033203	0.023438	0.009766	0.019531	0.039062	
9	0	0	0.001953	0.021484	0.041016	0	0.023438	0	0.011719	0.005859	0.001953	0.021484	0.001953	
12	0	0	0.009766	0.011719	0.017578	0	0.003906	0	0.003906	0.001953	0	0.029297	0	
13	0.001953	0	0.015625	0.009766	0.039062	0	0.009766	0	0.005859	0	0.001953	0.033203	0	
16	0.021484	0.033203	0.021484	0.009766	0.015625	0.035156	0.039062	0	0.003906	0.029297	0.013672	0.019531	0.042969	
19	0.015625	0.025391	0.046875	0.009766	0.005859	0.027344	0.042969	0	0	0.027344	0.015625	0.009766	0.044922	
23	0.007812	0.03125	0.011719	0.050781	0	0.11719	0.003906	0	0.011719	0.017578	0.056641	0.001953	0.046875	
24	0.003906	0.007812	0.074219	0.017578	0.015625	0.003906	0.011719	0	0.009766	0.011719	0.023438	0.037109	0.044922	
28	0	0	0.005859	0.021484	0.054688	0	0.015625	0	0.011719	0.005859	0	0.033203	0.001953	
33	0.025391	0.041016	0.033203	0.017578	0.009766	0.056641	0.023438	0	0.005859	0.027344	0.039062	0.001953	0.054688	
36	0.001953	0.009766	0.025391	0.003906	0.015625	0.003906	0.041016	0	0.005859	0.013672	0.007812	0.03125	0.025391	
39	0.013672	0	0.046875	0.019531	0.005859	0	0.041016	0	0.013672	0.013672	0.001953	0.009766	0.017578	
41	0.007812	0.005859	0.060547	0.013672	0.011719	0	0.037109	0	0	0.044922	0.011719	0.005859	0.009766	
44	0.017578	0.039062	0.03125	0.005859	0.005859	0.039062	0.013672	0	0.007812	0.023438	0.017578	0.025391	0.046875	
46	0.011719	0.017578	0.11133	0.009766	0.007812	0.011719	0.027344	0	0	0.005859	0.015625	0.003906	0.03320	
47	0.025391	0.015625	0.13281	0.003906	0.001953	0.009766	0.001953	0	0	0.011719	0.003906	0.009766	0.07812	
51	0.007812	0.007812	0.019531	0.039062	0.03125	0.021484	0.039062	0	0.001953	0.015625	0.013672	0.005859	0.02734	
52	0.001953	0.007812	0.03125	0.005859	0.013672	0.003906	0.015625	0	0	0.005859	0.001953	0.029297	0.02539	
53	0	0	0.082031	0.11133	0.017578	0	0	0	0.013672	0	0	0.009766		
57	0.013672	0.023438	0.007812	0.054688	0.001953	0.083984	0.019531	0	0.001953	0.052734	0.027344	0.005859	0.01171	
59	0.011719	0.011719	0.048828	0.005859	0.007812	0.015625	0.046875	0.005859	0	0.048828	0.015625	0.003906	0.01171	
62	0.037109	0.1582	0.013672	0.009766	0	0.20313	0	0	0.005859	0.001953	0.091797	0.003906	0.1347	
65	0.027344	0.056641	0.021484	0.011719	0.005859	0.019531	0.029297	0	0	0.048828	0.064453	0.003906	0.06054	
68	0	0	0.003906	0.021484	0.023438	0	0.003906	0	0.005859	0	0	0.013672	0.00195	
70	0.015625	0.023438	0.025391	0.011719	0.005859	0.005859	0.011719	0	0	0.023438	0.070312	0.001953	0.08203	
74	0.019531	0.064453	0.009766	0.039062	0	0.13867	0.001953	0	0.009766	0.007812	0.041016	0	0.06054	
77	0	0.095703	0	0.017578	0	0	0	0.005859	0	0	0.064453	0	0.4160	
79	0.001953	0	0.015625	0.11328	0.023438	0	0	0	0.017578	0.007812	0.005859	0.003906	0.00195	

No species(need to classify through trained model)



Tip

The data source is from Kaggle: https://www.kaggle.com/c/leaf-classification/data

Setup

Processing data

1. Processing data(Train data)

I. Encode the species of leaf and Split the train data of encoded species as “label”

II. Spilt the train data(label) into training data(label) and validation data(label).

III. Take the training and validation data into the array for fitting model’s shape and suitably identifying features.

Setup

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Encode the species of leaf and split the train.csv of encoded species as “label”

Train.csv

id	species	margin1	...	texture62	texture63	texture64
1	Acer_Opalus	0.007812	...	0.004883	0.000000	0.025391
2	Pterocarya_Stenoptera	0.005859	...	0.000977	0.039062	0.022461
3	Quercus_Hartwissiana	0.005859	...	0.000000	0.020508	0.002930
5	Tilia_Tomentosa	0.000000	...	0.017578	0.000000	0.047852
6	Quercus_Variabilis	0.005859	...	0.000000	0.000000	0.031250
...	...	...	...	...	...	...
1575	Magnolia_Salicifolia	0.060547	...	0.000000	0.000000	0.018555
1578	Acer_Pictum	0.001953	...	0.000977	0.000000	0.021484
1581	Alnus_Maximowiczii	0.001953	...	0.027344	0.000000	0.001953
1582	Quercus_Rubra	0.000000	...	0.000000	0.001953	0.002930
1584	Quercus_Afares	0.023438	...	0.023438	0.025391	0.022461

Split

Train data

	margin1	margin2	margin3	...	texture62	texture63	texture64
0	0.007812	0.023438	0.023438	...	0.004883	0.000000	0.025391
1	0.005859	0.000000	0.031250	...	0.000977	0.039062	0.022461
2	0.005859	0.009766	0.019531	...	0.000000	0.020508	0.002930
3	0.000000	0.003906	0.023438	...	0.017578	0.000000	0.047852
4	0.005859	0.003906	0.048828	...	0.000000	0.000000	0.031250
..	...	...	...	...	...	...	...
985	0.060547	0.119140	0.007812	...	0.000000	0.000000	0.018555
986	0.001953	0.003906	0.021484	...	0.000977	0.000000	0.021484
987	0.001953	0.003906	0.000000	...	0.027344	0.000000	0.001953
988	0.000000	0.000000	0.046875	...	0.000000	0.001953	0.002930
989	0.023438	0.019531	0.031250	...	0.023438	0.025391	0.022461

Label

```
The label of train.csv: [ 3 49 65 94 84 40 54 78 53 89 98 16 74 50 58 31 4
 15  6 73 22 73 31 36 27 94 88 12 28 21 25 20 60 84 65 69 58 23 76 18 52
 54  9 48 47 64 81 83 36 58 21 81 20 62 88 34 92 79 82 20 32  4 84 36 35
 72 60 71 72 52 50 54 11 51 18 47  5  8 37 97 20 33  1 59  1 56  1  9 57
 20 79 29 16 32 54 93 10 46 59 84 76 15 10 15  0 69  4 51 51 94 36 39 62
  2 24 26 35 25 87  0 55 34 38  1 45  7 93 56 38 21 51 75 81 74 33 20 37
  9 40 60 31 83 50 71 67 30 66  1 43 61 23 65 84 87 46 57 16  2 28 12 96
 44 76 29 75 41 87 67 61 30  5 12 62  3 83 81  6 85  4 37 57 84 39 71 61
  6 76 14 31 98 40 17 51 16 42 63 86 37 69 86 71 80 78 14 35 25  5 39  8
  9 26 44 60 13 14 77 13 80 87 18 60 78 92 51 45 78 41 51 30 14 35 46 21
  8  6 92 38 40 15 32 17 93 71 92 27 78 15 19 60 21 38 36 49 74 67 95 31
 82 45 16 83 63 80 42 22 74 53 15 44 47 57 94 76 17 32 24 15 93 24 80 59
 46 12 51 77 79 70 69 16  2 63 83 55 12 53  1 67  0  2 36 42 10  9 52 59
  6 22 86 31 51 37 43 75 90 24 86 96 45 32 98 36 66 48 73 73 79 56 41 21
 25 27 97 18 44 45 40 80 63 20 35  0  8 27 25 35 59 61 21 37 29  6 19 78
 50 54 37 93 33 46 79 59 29 43  0 23 17 38 66 38 89 17 25 31 65 10 26 86
 58 42 46 24 95 93  8 53 32 14 10 94  8  8 64 44 74 30 97 22 11 68 56 90
 96 16 43 57 91 24 28 82 90 64 61 92 28 84 70 45 85 34  7 88 89 61 26 88
 41 46  8 91 41 14 98 28 26 36 70 74  7 52 70 42 66 22 13 44 91 53 22 16
 40 40 28 70  6 60 95 23 16 50 29 49  9 18 55 63 60 19 28 30 31 85 66 88
 63 83 64 96 13 34 27 95 36 72 29 91 22 65 71 66 11 32  2 75 39  5 37 67
 81 55 61 57 81 82 63 55 54 35 86 25 24 96 10 58 59 28 89 54 52 85 68 69
  8 39 95 39 82 48 74 52 74 55  9 47 84 91 12 96 82 64  7 40 73 77 11 36
 68 23 28 46 75 43  2 11 47 53 56 62 62 80 56 30  3 88 37 33 73 76 21  5
 76 87 68 83 62 57 47 19 88 96 42 23 44 87 82 49 63 24 94 69 54  5 79 43
 12 50  5 52 92  4 84  1 33 49 26 18 44 13 24 73 89 78 67 41 11 46 47 69
  0 18 98 44 85 29 53  1 45  3  9 13  2 66 59 79  6 17 43 83 26  1 12 49
 71 89 58 93 39 42 15 38 55 15 93  4 90 88 55 40 55 17 34 94 57 92 81 26
 60 89 49 89 30 65 58  4 19  4 76 74 71 21 54 13 16 72 68 62 61 25 72  7
 12 18 77 90 62 14  3 78 65 37 27 50 95 98 60 72 58 38 87 93 19  7 83 50
  3 91 77  7 64 61 69 23 76 65 48 41 92 20 91 18 70  9  9 29 85 67  0 35
 98 91 90 31 53 39 24 85 96 17  7 11 96 39 56 90 79 45 64 97 41 19 74 11
 10 62 95 28 96 10  7 68  7 93 34 42 68 41 14 22 58 12 71 27 98 72 91  3
 43 19 61 75 20 81 63 67 56 26 47 11 31 57 62 66 19 75 97 94 13 75 95 32
 50 97 52 87 32  3 47 77 48 33 73 64 49 68 43 94 77 68 47 82  2 30 23 33
 34 66 33 35 88 68 27 87 54 79 34 67 65 18  4 26 30 52 86  0 29 80 67 95
 39 25 70 58 35 27 17 38 91 13 23 77 79 77 22 49 98 48 46 48  5 63 97 80
 53 20 25 78 10 65 33 41 85 90 98 97 71 95 52  3 29 69 51 70 27 22 34  6
 48 72 21 89 17 97 72 80 10 57 64 92 38 15 73 87 73 48 42 82 33 56  3 42
  1 53 55 90 19  6 30 86 64 49  2  8 45 76 92  0 23 69 59 80 90 32  5 59
 85 89 94 45 48 86 81 14  4 77 56 82  2 85 70 88  0 75 14 86 81 97 70 72
 34 40  5 11 78 50]
```

Setup

Processing data

1. Processing data(Train data)

I.Encode the species of leaf and Split the train data of encoded species as "label"

II.Spilt the train data(label) into training data(label) and validation data(label).

III.Take the training and validation data into the array for fitting model's shape and suitably identifying features.

Spilt the train data(label) into training data(label) and validation data(label).

Train data(990 data)

	margin1	margin2	margin3	...	texture62	texture63	texture64
0	0.007812	0.023438	0.023438	...	0.004883	0.000000	0.025391
1	0.005859	0.000000	0.031250	...	0.000977	0.039062	0.022461
2	0.005859	0.009766	0.019531	...	0.000000	0.020508	0.002930
3	0.000000	0.003906	0.023438	...	0.017578	0.000000	0.047852
4	0.005859	0.003906	0.048828	...	0.000000	0.000000	0.031250
..	...	...	...	...	...	...	...
985	0.060547	0.119140	0.007812	...	0.000000	0.000000	0.018555
986	0.001953	0.003906	0.021484	...	0.000977	0.000000	0.021484
987	0.001953	0.003906	0.000000	...	0.027344	0.000000	0.001953
988	0.000000	0.000000	0.046875	...	0.000000	0.001953	0.002930
989	0.023438	0.019531	0.031250	...	0.023438	0.025391	0.022461

Split

[margin1,margin2,......]

Training data(792 data)

```
[[-0.88257543 -0.73488047  1.63472622 ...  0.80643593 -0.65214311
  -0.81045405]
 [ 0.00839582 -0.48340807  0.95429928 ...  0.0556156  -0.65214311
  -0.72463124]
 [-0.78358426 -0.73488047 -1.08702026 ...  0.13070533 -0.08540955
   1.29231481]
 ...
 [-0.68459308 -0.63430181 -0.40659332 ... -0.52001246  4.16538229
  -0.46716279]
 [-0.18958653 -0.63430181  0.19823493 ... -0.44492274 -0.51045972
   0.47693214]
 [-0.88257543 -0.73488047  2.54194924 ...  0.55615395 -0.43958175
  -0.85338743]]
```

[margin1,margin2,......]

Validation data(198 data)

```
[[ 1.09734942  1.12595348 -0.02856115 ... -0.52001246  1.33156943
  -0.5529856 ]
 [-0.88257543 -0.73488047 -1.16261896 ... -0.52001246 -0.65214311
  -0.38133997]
 [-0.88257543 -0.73488047 -0.6333894  ...  0.25582069  0.26883519
  -0.38133997]
 ...
 [ 0.4044112  -0.03077835  0.95429928 ... -0.52001246 -0.65214311
  -0.12382758]
 [-0.38756887 -0.58401248 -0.93582288 ... -0.34482019 -0.65214311
  -0.85338743]
 [-0.88257543 -0.73488047 -0.40659332 ... -0.52001246  0.97732468
  -0.85338743]]
```

Setup

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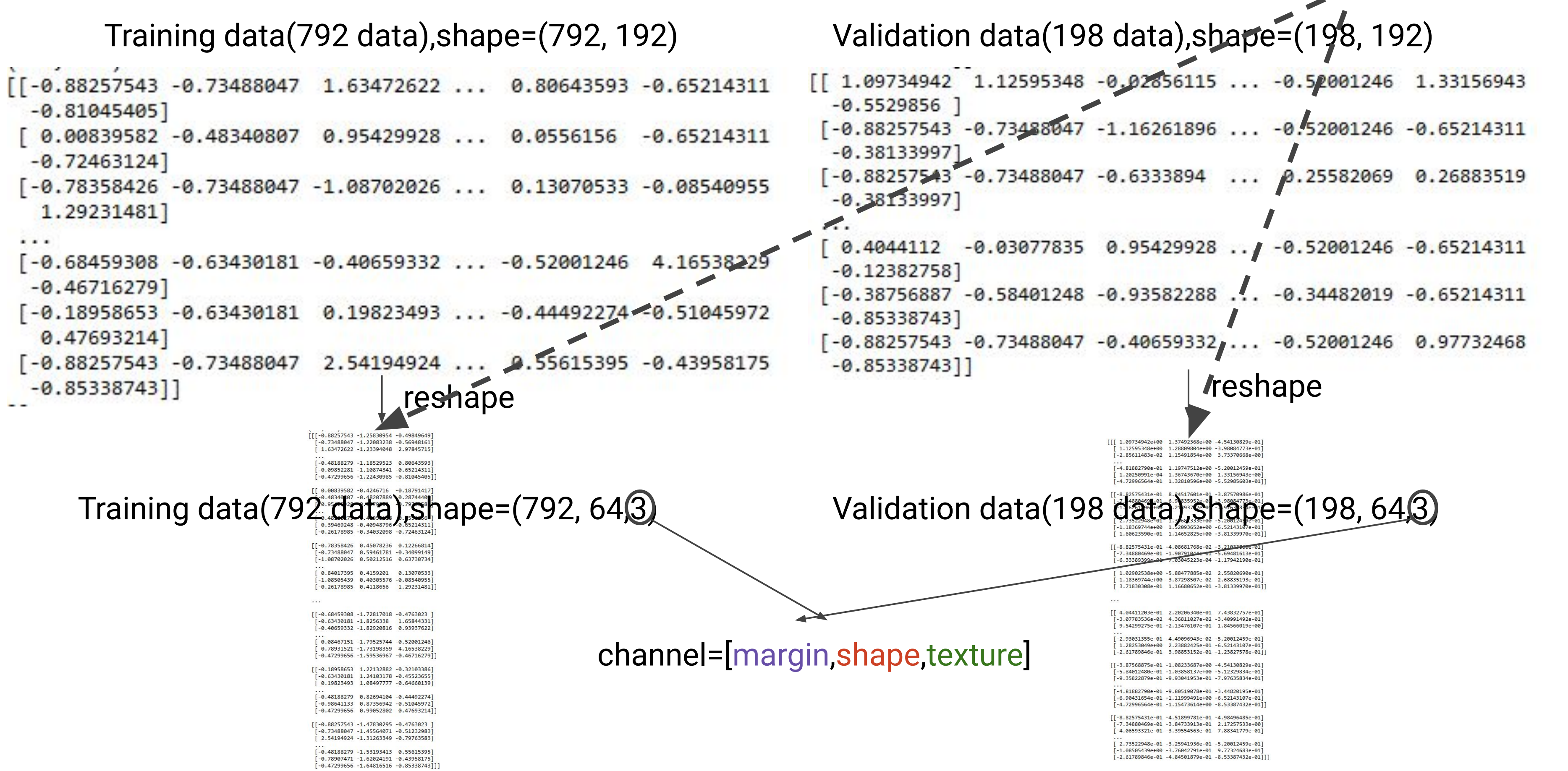
1. Processing data(Train data)

I.Encode the species of leaf and Split the train data of encoded species as "label"

II.Spilt the train data(label) into training data(label) and validation data(label).

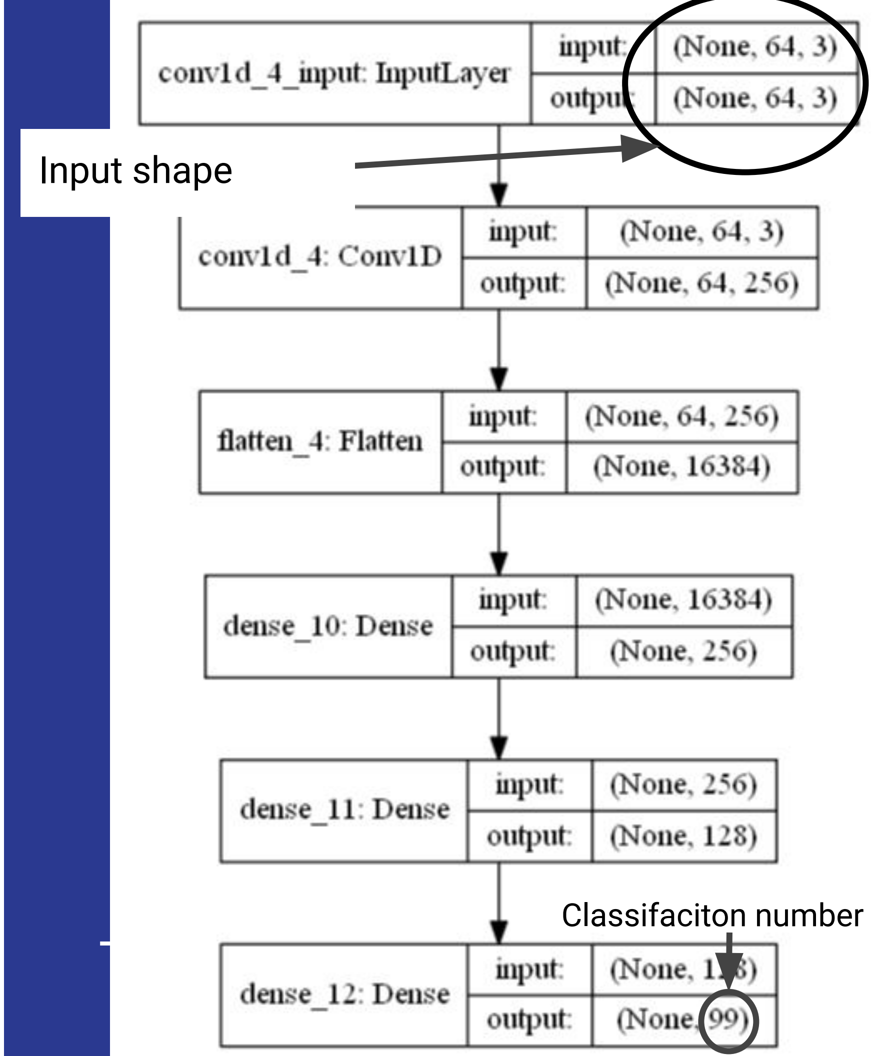
III.Take the training and validation data into the array for fitting model's shape and suitably identifying features.

Take the training and validation data into the array **for fitting model’s shape and suitably identifying features.**



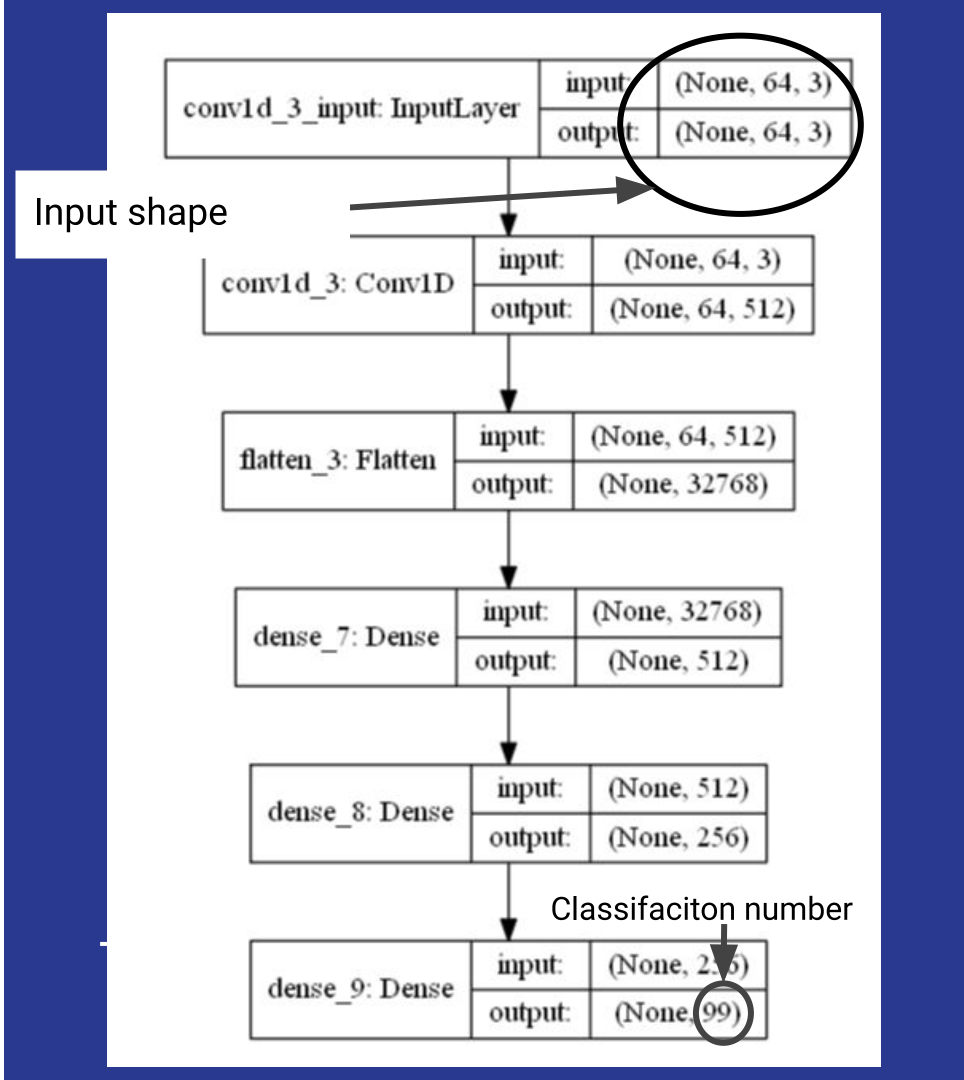
Setup

Model Structure:Model0



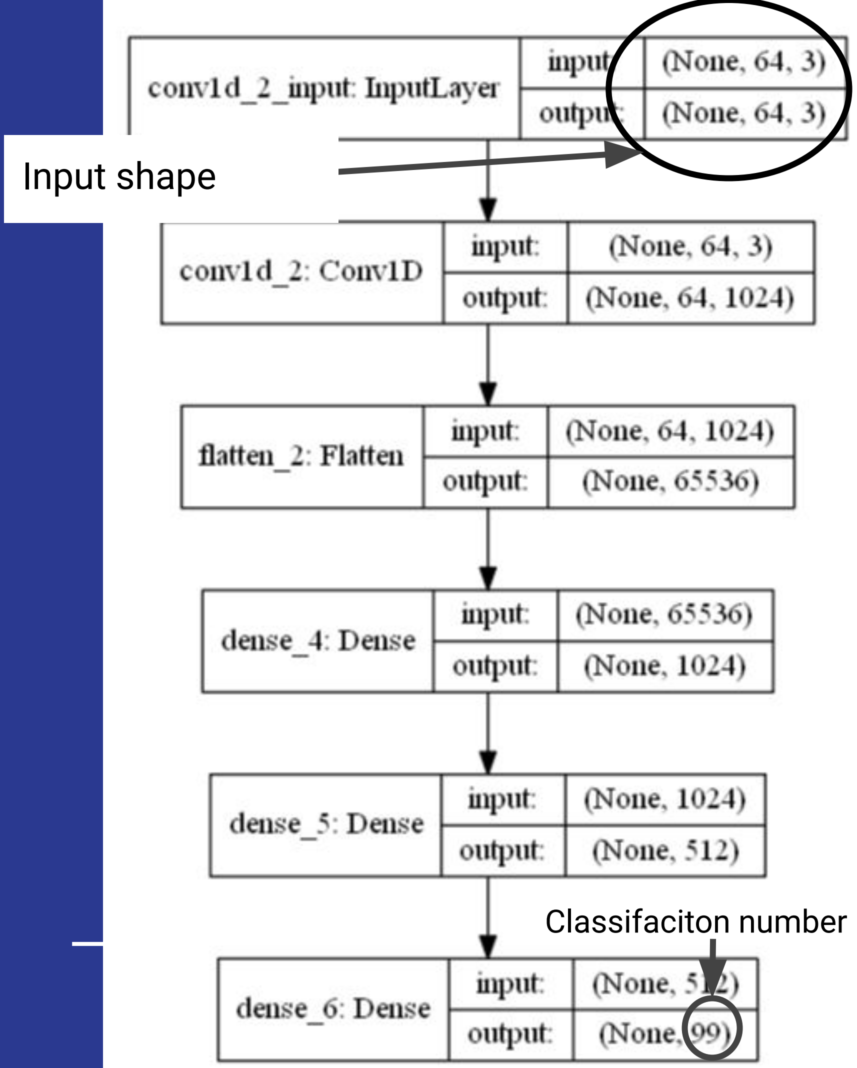
Setup

Model Structure:Model1



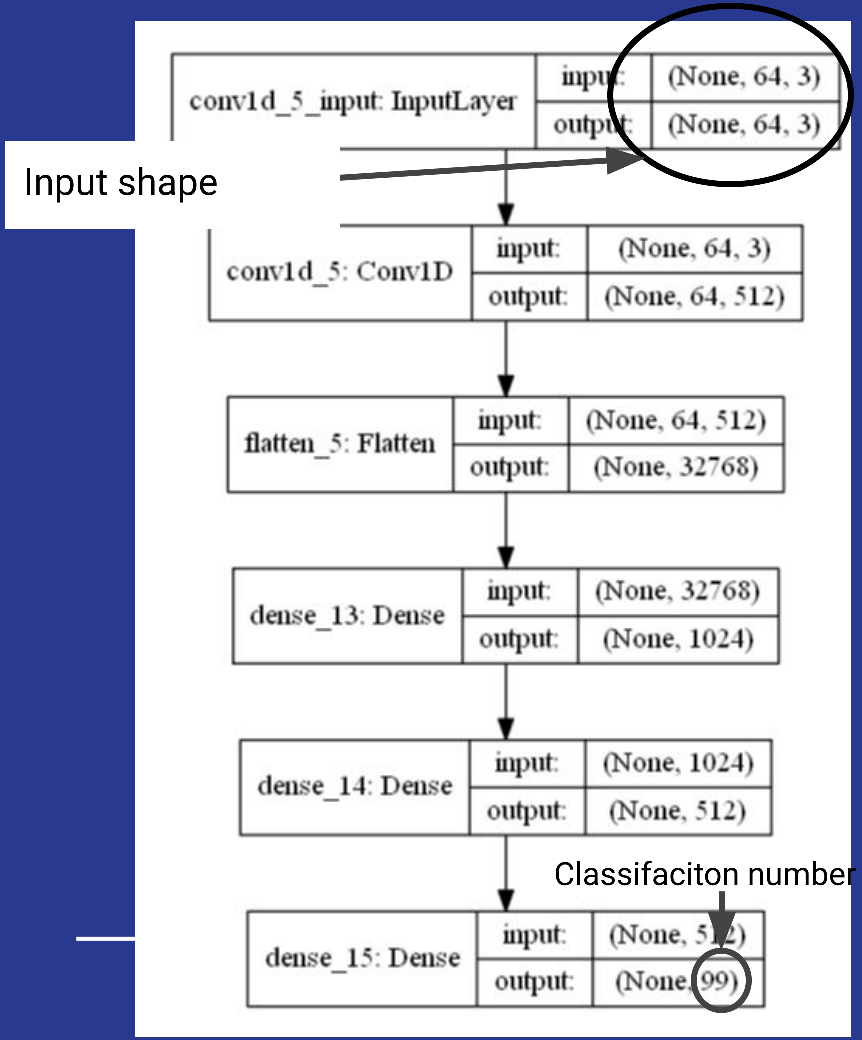
Setup

Model Structure:Model2



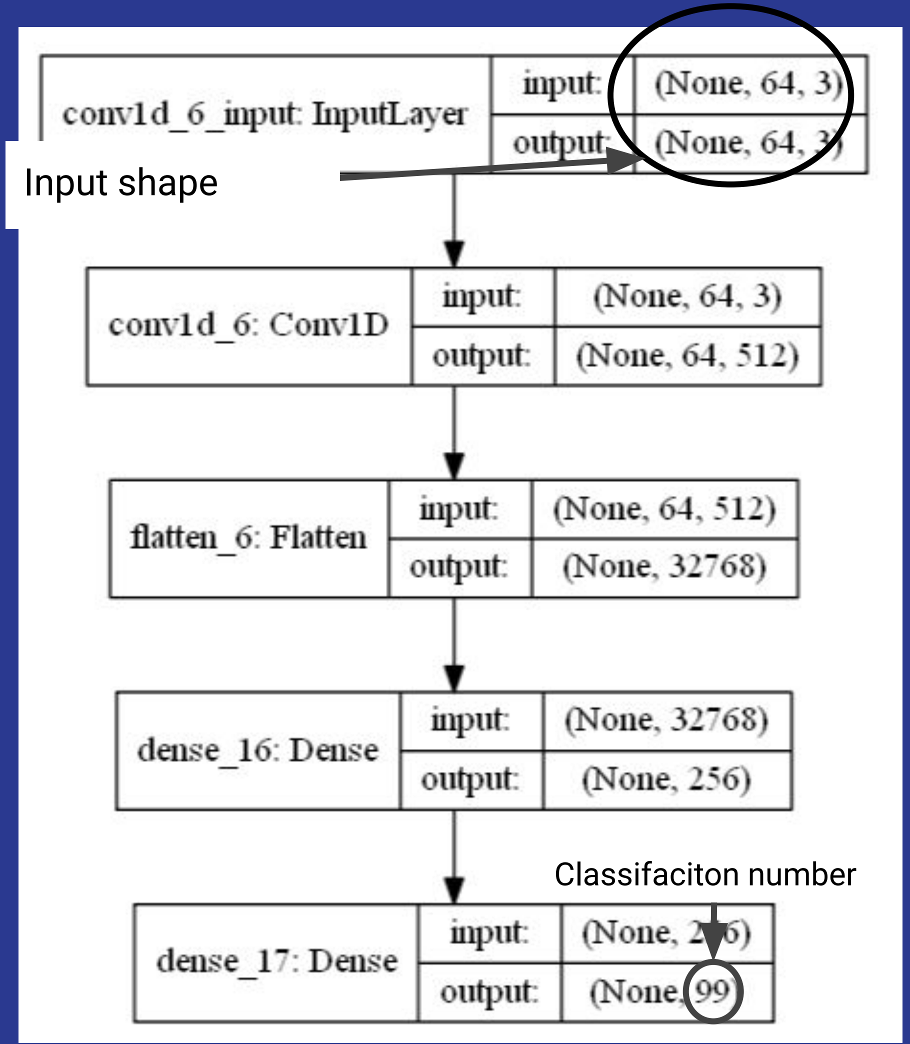
Setup

Model Structure:Model3



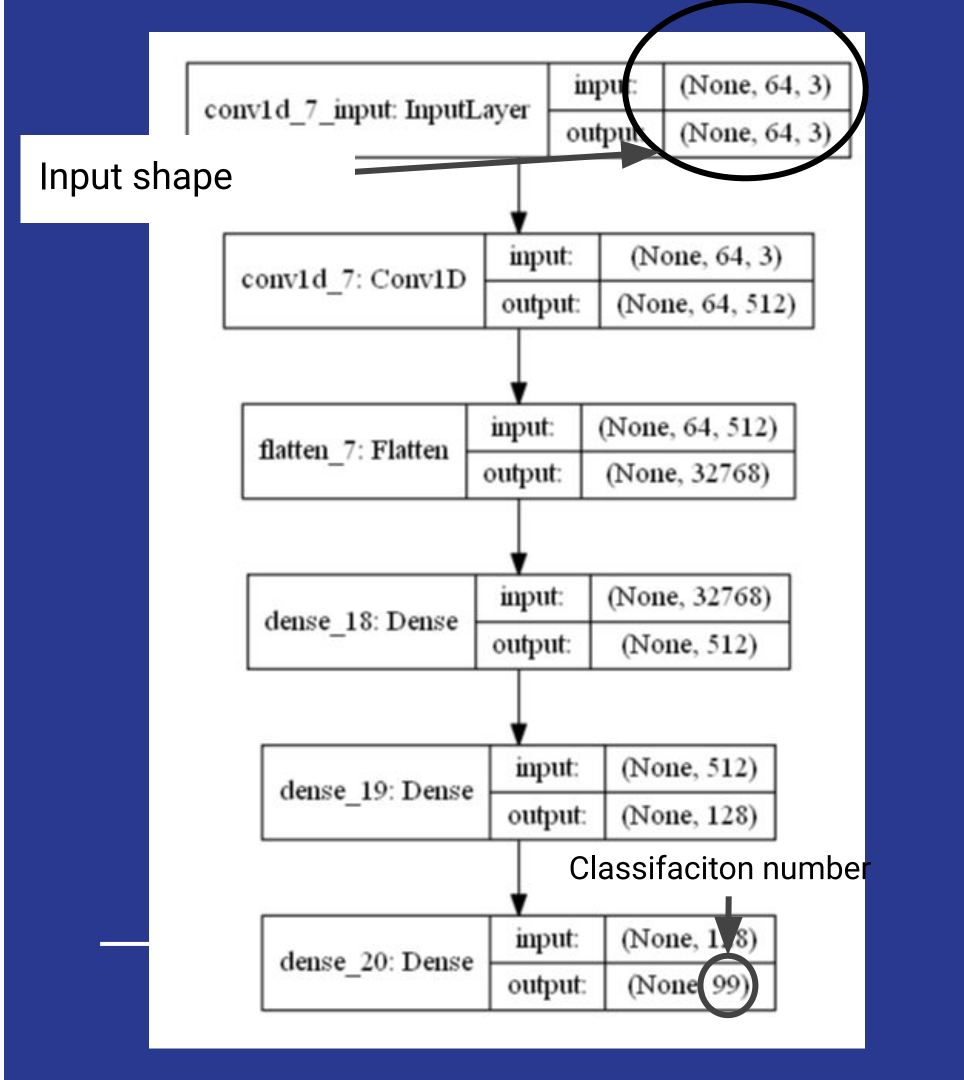
Setup

Model Structure:Model4

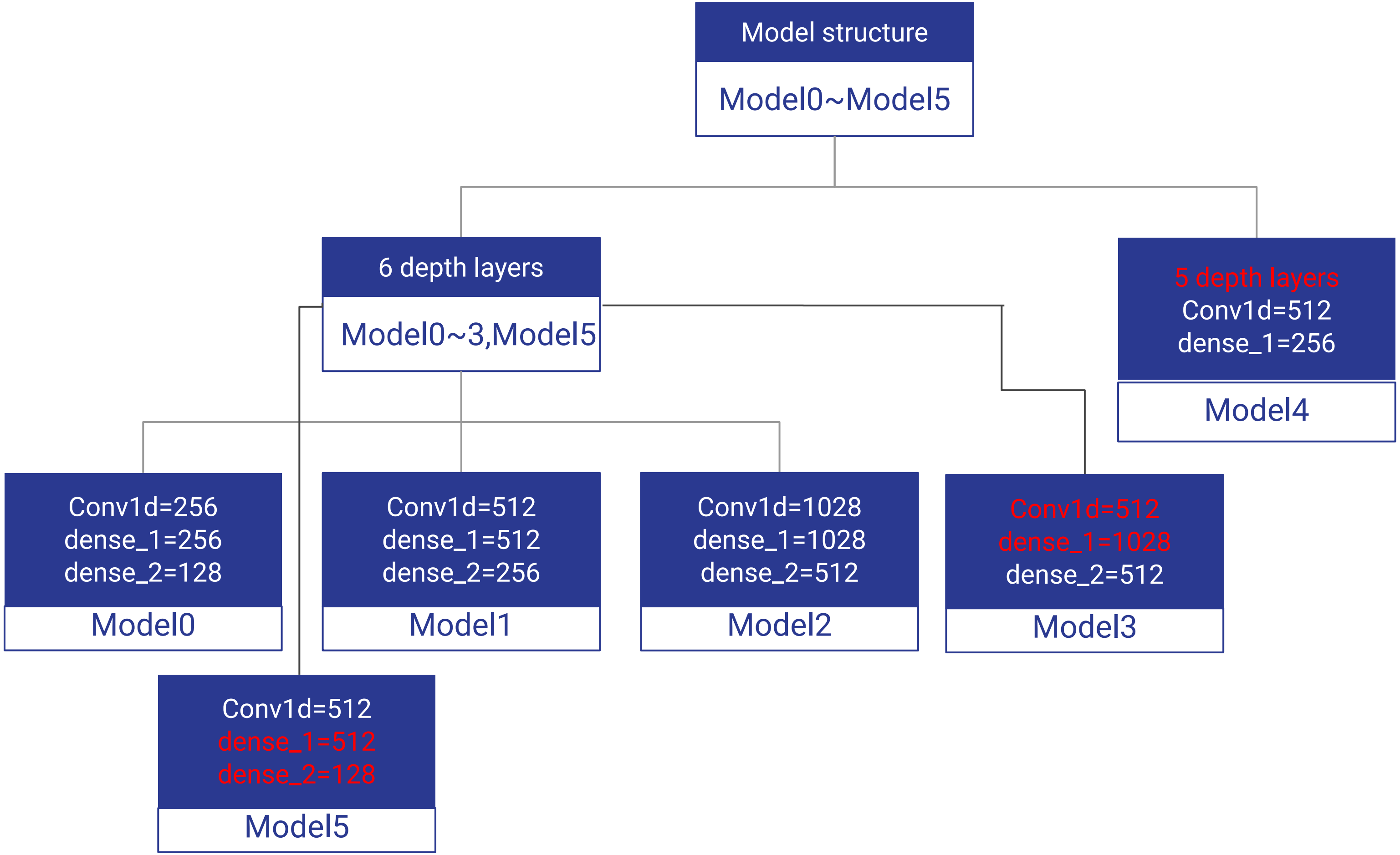


Setup

Model Structure:Model5



Model structure



Result

Fitting environment(same with each model)

1. The fitting environment is(for each model) :

   I.epochs=15

   II.batch_size=16

   III.Use the training data and validation data.

Fitting progress: Model0

Overfit happened

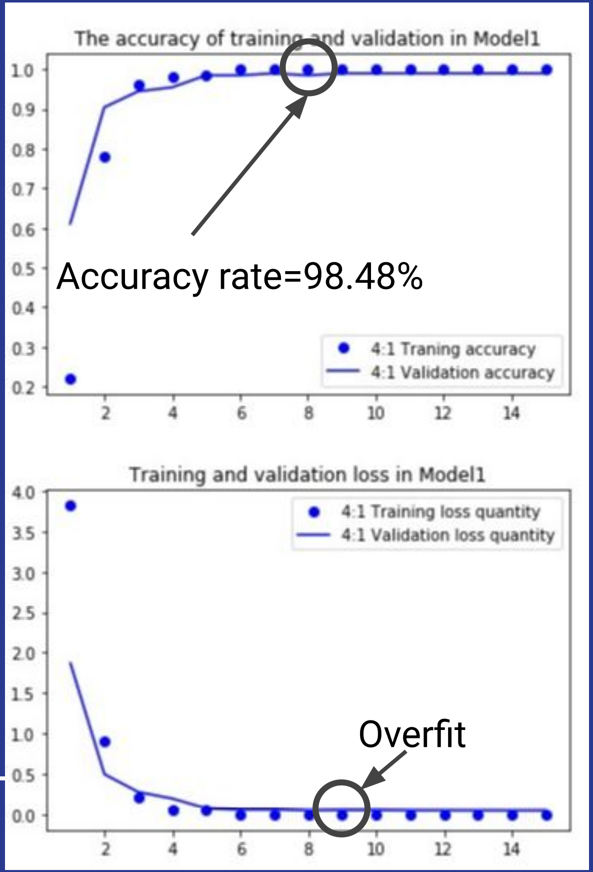
Accuracy rate

```
Epoch 1/15
792/792 [==============================] - 30s 38ms/step - loss: 3.8213 - acc: 0.2210 - val_loss: 1.8698 - val_acc: 0.6111
Epoch 2/15
792/792 [==============================] - 30s 37ms/step - loss: 0.9059 - acc: 0.7816 - val_loss: 0.4979 - val_acc: 0.9040
Epoch 3/15
792/792 [==============================] - 30s 38ms/step - loss: 0.2068 - acc: 0.9596 - val_loss: 0.2771 - val_acc: 0.9444
Epoch 4/15
792/792 [==============================] - 30s 38ms/step - loss: 0.0619 - acc: 0.9811 - val_loss: 0.1965 - val_acc: 0.9545
Epoch 5/15
792/792 [==============================] - 31s 39ms/step - loss: 0.0532 - acc: 0.9861 - val_loss: 0.0739 - val_acc: 0.9848
Epoch 6/15
792/792 [==============================] - 30s 38ms/step - loss: 0.0081 - acc: 1.0000 - val_loss: 0.0600 - val_acc: 0.9848
Epoch 7/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0046 - acc: 1.0000 - val_loss: 0.0605 - val_acc: 0.9899
Epoch 8/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0033 - acc: 1.0000 - val_loss: 0.0504 - val_acc: 0.9848
Epoch 9/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0026 - acc: 1.0000 - val_loss: 0.0531 - val_acc: 0.9899
Epoch 10/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0022 - acc: 1.0000 - val_loss: 0.0530 - val_acc: 0.9899
Epoch 11/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0019 - acc: 1.0000 - val_loss: 0.0502 - val_acc: 0.9899
Epoch 12/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0017 - acc: 1.0000 - val_loss: 0.0497 - val_acc: 0.9899
Epoch 13/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0015 - acc: 1.0000 - val_loss: 0.0491 - val_acc: 0.9899
Epoch 14/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0014 - acc: 1.0000 - val_loss: 0.0488 - val_acc: 0.9899
Epoch 15/15
792/792 [==============================] - 30s 37ms/step - loss: 0.0013 - acc: 1.0000 - val_loss: 0.0486 - val_acc: 0.9899
```

Result

Model0 result

1. Accuracy rate= 98.48%
2. Overfit happened epochs=9



Fitting progress: Model1

Overfit happened

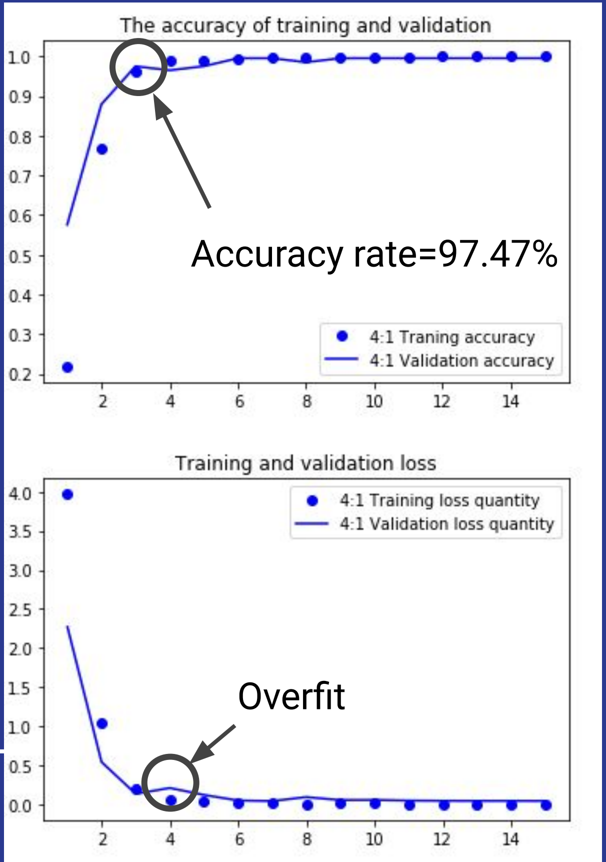
Accuracy rate

```
Epoch 1/15
792/792 [==============================] - 8s 10ms/step - loss: 3.9693 - acc: 0.2184 - val_loss: 2.2701 - val_acc: 0.5758
Epoch 2/15
792/792 [==============================] - 8s 10ms/step - loss: 1.0422 - acc: 0.7677 - val_loss: 0.5421 - val_acc: 0.8788
Epoch 3/15
792/792 [==============================] - 8s 10ms/step - loss: 0.2041 - acc: 0.9609 - val_loss: 0.1351 - val_acc: 0.9747
Epoch 4/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0651 - acc: 0.9874 - val_loss: 0.2105 - val_acc: 0.9646
Epoch 5/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0442 - acc: 0.9899 - val_loss: 0.1216 - val_acc: 0.9747
Epoch 6/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0282 - acc: 0.9937 - val_loss: 0.0506 - val_acc: 0.9949
Epoch 7/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0228 - acc: 0.9962 - val_loss: 0.0428 - val_acc: 0.9949
Epoch 8/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0070 - acc: 0.9987 - val_loss: 0.0938 - val_acc: 0.9848
Epoch 9/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0102 - acc: 0.9975 - val_loss: 0.0554 - val_acc: 0.9949
Epoch 10/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0107 - acc: 0.9987 - val_loss: 0.0573 - val_acc: 0.9949
Epoch 11/15
792/792 [==============================] - 7s 9ms/step - loss: 0.0048 - acc: 0.9987 - val_loss: 0.0492 - val_acc: 0.9949
Epoch 12/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0022 - acc: 1.0000 - val_loss: 0.0464 - val_acc: 0.9949
Epoch 13/15
792/792 [==============================] - 7s 9ms/step - loss: 0.0018 - acc: 1.0000 - val_loss: 0.0451 - val_acc: 0.9949
Epoch 14/15
792/792 [==============================] - 7s 9ms/step - loss: 0.0016 - acc: 1.0000 - val_loss: 0.0454 - val_acc: 0.9949
Epoch 15/15
792/792 [==============================] - 7s 9ms/step - loss: 0.0014 - acc: 1.0000 - val_loss: 0.0445 - val_acc: 0.9949
```

Result

Model1

1. Accuracy rate= 97.47%
2. Overfit happened epochs=4



Fitting progress: Model2

Overfit happened

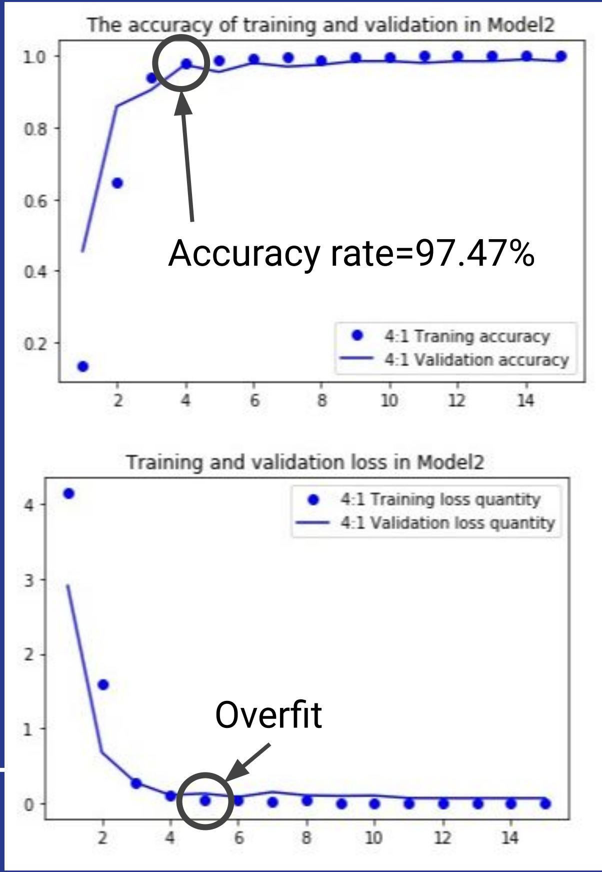
Accuracy rate

```
Epoch 1/15
792/792 [==============================] - 2s 3ms/step - loss: 4.1455 - acc: 0.1351 - val_loss: 2.9070 - val_acc: 0.4545
Epoch 2/15
792/792 [==============================] - 2s 2ms/step - loss: 1.5922 - acc: 0.6465 - val_loss: 0.6796 - val_acc: 0.8586
Epoch 3/15
792/792 [==============================] - 2s 2ms/step - loss: 0.2797 - acc: 0.9381 - val_loss: 0.2728 - val_acc: 0.9040
Epoch 4/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0999 - acc: 0.9773 - val_loss: 0.1079 - val_acc: 0.9747
Epoch 5/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0478 - acc: 0.9886 - val_loss: 0.1273 - val_acc: 0.9545
Epoch 6/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0352 - acc: 0.9924 - val_loss: 0.0820 - val_acc: 0.9798
Epoch 7/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0170 - acc: 0.9987 - val_loss: 0.1473 - val_acc: 0.9697
Epoch 8/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0435 - acc: 0.9861 - val_loss: 0.1029 - val_acc: 0.9747
Epoch 9/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0091 - acc: 0.9975 - val_loss: 0.0958 - val_acc: 0.9848
Epoch 10/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0102 - acc: 0.9975 - val_loss: 0.1003 - val_acc: 0.9848
Epoch 11/15
792/792 [==============================] - 2s 3ms/step - loss: 0.0035 - acc: 1.0000 - val_loss: 0.0673 - val_acc: 0.9798
Epoch 12/15
792/792 [==============================] - 2s 3ms/step - loss: 0.0023 - acc: 1.0000 - val_loss: 0.0663 - val_acc: 0.9848
Epoch 13/15
792/792 [==============================] - 2s 3ms/step - loss: 0.0019 - acc: 1.0000 - val_loss: 0.0657 - val_acc: 0.9848
Epoch 14/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0017 - acc: 1.0000 - val_loss: 0.0657 - val_acc: 0.9899
Epoch 15/15
792/792 [==============================] - 2s 2ms/step - loss: 0.0015 - acc: 1.0000 - val_loss: 0.0658 - val_acc: 0.9848
```

Result

Model2 result

1. Accuracy rate= 97.47%
2. Overfit happened epochs=5



Fitting progress: Model3

Accuracy rate

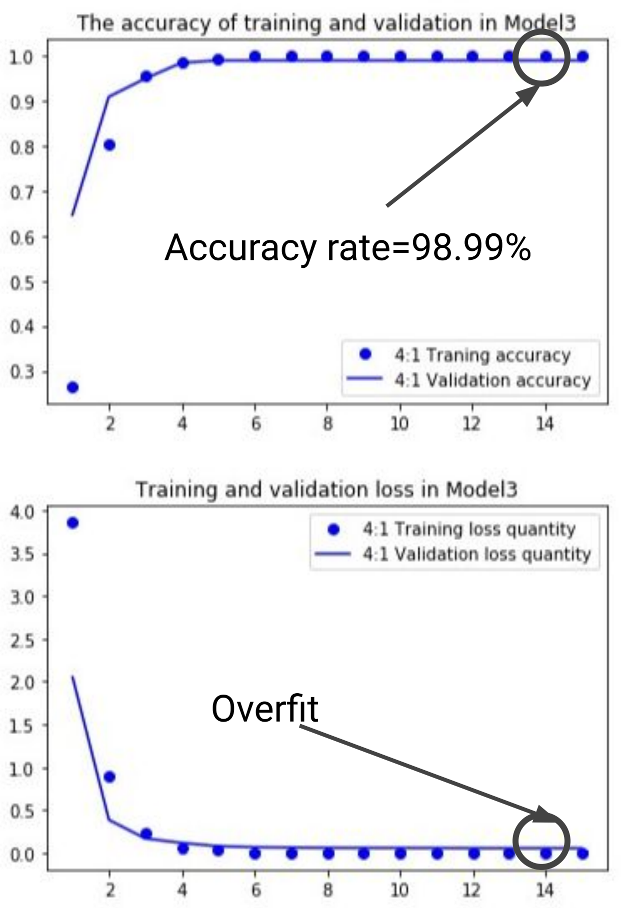
Overfit happened

```
Epoch 1/15
792/792 [==============================] - 16s 20ms/step - loss: 3.8588 - acc: 0.2652 - val_loss: 2.0517 - val_acc: 0.6465
Epoch 2/15
792/792 [==============================] - 15s 19ms/step - loss: 0.9014 - acc: 0.8030 - val_loss: 0.3854 - val_acc: 0.9091
Epoch 3/15
792/792 [==============================] - 16s 20ms/step - loss: 0.2313 - acc: 0.9571 - val_loss: 0.1691 - val_acc: 0.9495
Epoch 4/15
792/792 [==============================] - 16s 21ms/step - loss: 0.0569 - acc: 0.9874 - val_loss: 0.1173 - val_acc: 0.9848
Epoch 5/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0306 - acc: 0.9937 - val_loss: 0.0788 - val_acc: 0.9899
Epoch 6/15
792/792 [==============================] - 15s 19ms/step - loss: 0.0072 - acc: 1.0000 - val_loss: 0.0670 - val_acc: 0.9899
Epoch 7/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0036 - acc: 1.0000 - val_loss: 0.0635 - val_acc: 0.9899
Epoch 8/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0027 - acc: 1.0000 - val_loss: 0.0600 - val_acc: 0.9899
Epoch 9/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0023 - acc: 1.0000 - val_loss: 0.0589 - val_acc: 0.9899
Epoch 10/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0020 - acc: 1.0000 - val_loss: 0.0582 - val_acc: 0.9899
Epoch 11/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0017 - acc: 1.0000 - val_loss: 0.0574 - val_acc: 0.9899
Epoch 12/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0015 - acc: 1.0000 - val_loss: 0.0555 - val_acc: 0.9899
Epoch 13/15
792/792 [==============================] - 16s 20ms/step - loss: 0.0014 - acc: 1.0000 - val_loss: 0.0549 - val_acc: 0.9899
Epoch 14/15
792/792 [==============================] - 15s 19ms/step - loss: 0.0013 - acc: 1.0000 - val_loss: 0.0553 - val_acc: 0.9899
Epoch 15/15
792/792 [==============================] - 15s 19ms/step - loss: 0.0012 - acc: 1.0000 - val_loss: 0.0545 - val_acc: 0.9899
```

Result

Model3 result

1. Accuracy rate= 98.99%
2. Overfit happened epochs=14



Fitting progress: Model4

Accuracy rate

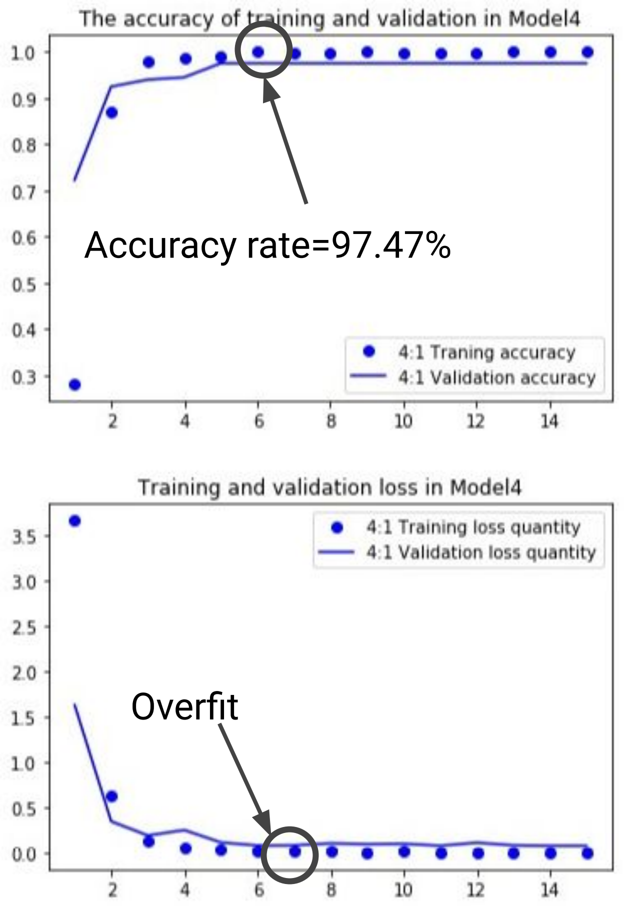
Overfit happened

```
Epoch 1/15
792/792 [==============================] - 4s 5ms/step - loss: 3.6674 - acc: 0.2816 - val_loss: 1.6294 - val_acc: 0.7222
Epoch 2/15
792/792 [==============================] - 4s 5ms/step - loss: 0.6367 - acc: 0.8699 - val_loss: 0.3461 - val_acc: 0.9242
Epoch 3/15
792/792 [==============================] - 4s 5ms/step - loss: 0.1247 - acc: 0.9773 - val_loss: 0.1908 - val_acc: 0.9394
Epoch 4/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0523 - acc: 0.9861 - val_loss: 0.2502 - val_acc: 0.9444
Epoch 5/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0410 - acc: 0.9899 - val_loss: 0.1139 - val_acc: 0.9747
Epoch 6/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0109 - acc: 1.0000 - val_loss: 0.0798 - val_acc: 0.9747
Epoch 7/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0110 - acc: 0.9962 - val_loss: 0.0815 - val_acc: 0.9747
Epoch 8/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0160 - acc: 0.9975 - val_loss: 0.1042 - val_acc: 0.9747
Epoch 9/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0063 - acc: 1.0000 - val_loss: 0.0953 - val_acc: 0.9747
Epoch 10/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0120 - acc: 0.9987 - val_loss: 0.0995 - val_acc: 0.9747
Epoch 11/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0048 - acc: 0.9987 - val_loss: 0.0772 - val_acc: 0.9747
Epoch 12/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0082 - acc: 0.9987 - val_loss: 0.1112 - val_acc: 0.9747
Epoch 13/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0035 - acc: 1.0000 - val_loss: 0.0819 - val_acc: 0.9747
Epoch 14/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0028 - acc: 1.0000 - val_loss: 0.0770 - val_acc: 0.9747
Epoch 15/15
792/792 [==============================] - 4s 5ms/step - loss: 0.0025 - acc: 1.0000 - val_loss: 0.0769 - val_acc: 0.9747
```

Result

Model4 result

1. Accuracy rate= 97.47%
2. Overfit happened epochs=7



Fitting progress: Model5

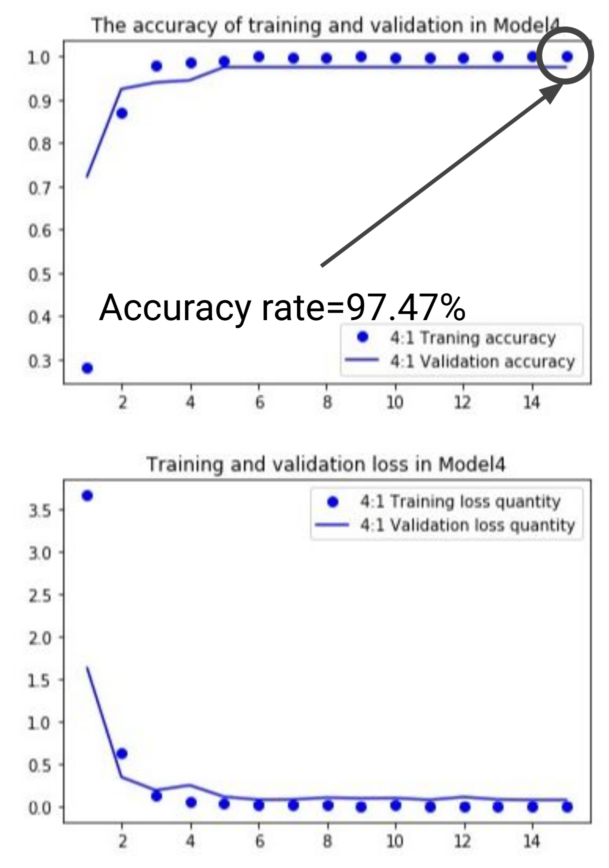
Accuracy rate

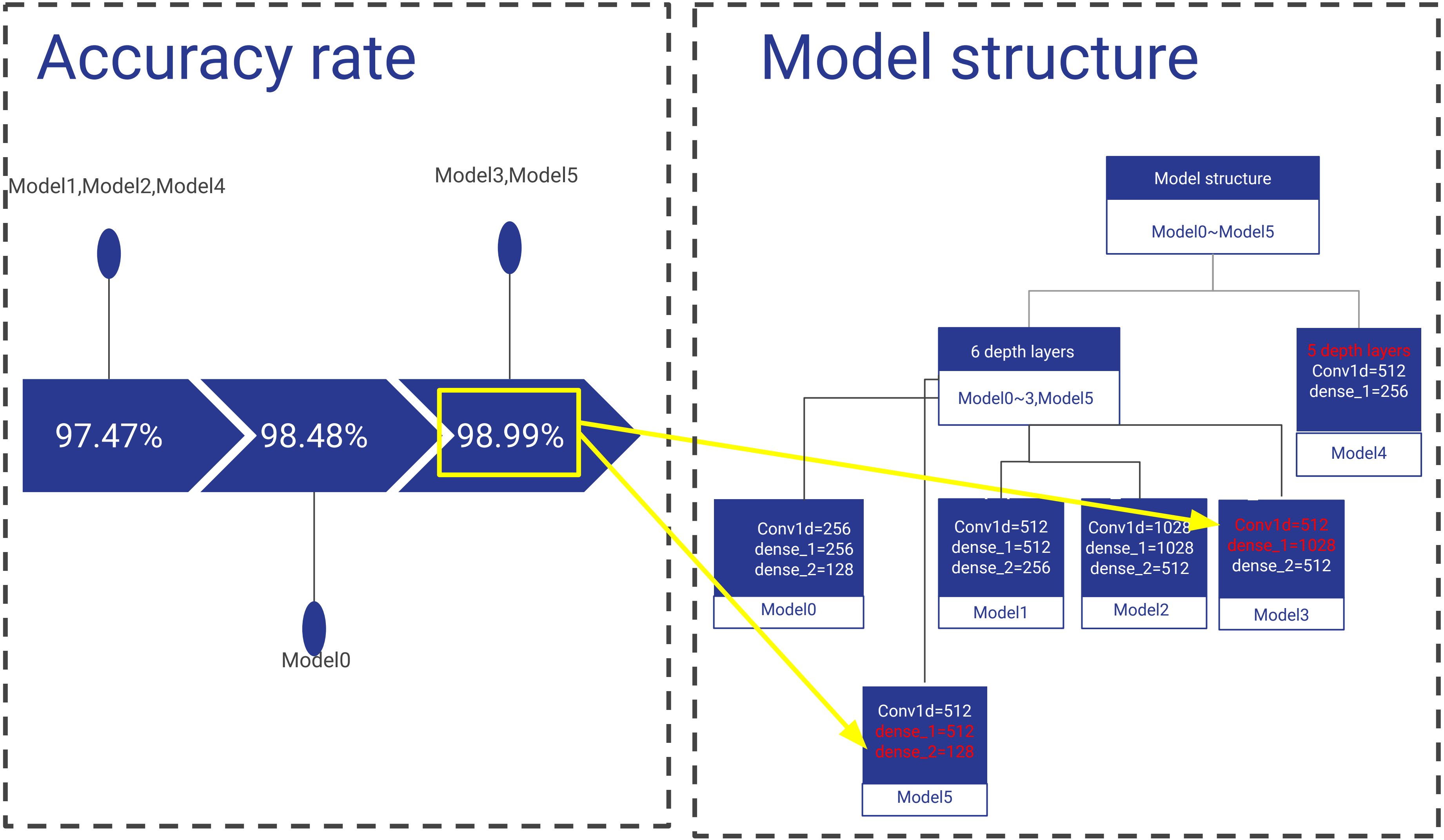
```
Epoch 1/15
792/792 [==============================] - 8s 11ms/step - loss: 4.1181 - acc: 0.1528 - val_loss: 2.8541 - val_acc: 0.4848
Epoch 2/15
792/792 [==============================] - 8s 11ms/step - loss: 1.3932 - acc: 0.7096 - val_loss: 0.5805 - val_acc: 0.8586
Epoch 3/15
792/792 [==============================] - 8s 11ms/step - loss: 0.2547 - acc: 0.9495 - val_loss: 0.2601 - val_acc: 0.9141
Epoch 4/15
792/792 [==============================] - 8s 11ms/step - loss: 0.0889 - acc: 0.9773 - val_loss: 0.1478 - val_acc: 0.9697
Epoch 5/15
792/792 [==============================] - 8s 11ms/step - loss: 0.0561 - acc: 0.9899 - val_loss: 0.0974 - val_acc: 0.9798
Epoch 6/15
792/792 [==============================] - 9s 11ms/step - loss: 0.0302 - acc: 0.9937 - val_loss: 0.0717 - val_acc: 0.9747
Epoch 7/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0075 - acc: 0.9987 - val_loss: 0.0632 - val_acc: 0.9848
Epoch 8/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0132 - acc: 0.9962 - val_loss: 0.0696 - val_acc: 0.9899
Epoch 9/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0035 - acc: 1.0000 - val_loss: 0.0632 - val_acc: 0.9899
Epoch 10/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0026 - acc: 1.0000 - val_loss: 0.0596 - val_acc: 0.9899
Epoch 11/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0022 - acc: 1.0000 - val_loss: 0.0583 - val_acc: 0.9899
Epoch 12/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0019 - acc: 1.0000 - val_loss: 0.0576 - val_acc: 0.9899
Epoch 13/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0017 - acc: 1.0000 - val_loss: 0.0571 - val_acc: 0.9899
Epoch 14/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0015 - acc: 1.0000 - val_loss: 0.0561 - val_acc: 0.9899
Epoch 15/15
792/792 [==============================] - 8s 10ms/step - loss: 0.0014 - acc: 1.0000 - val_loss: 0.0545 - val_acc: 0.9899
```

Result

Model5 result

1. Accuracy rate= 98.99%
2. Overfit happened epochs=None




Accuracy rate
Model1,Model2,Model4
Model3,Model5
97.47%
98.48%
98.99%
Model0
Model structure
Model structure
Model0~Model5
6 depth layers
Model0~3,Model5
5 depth layers
Conv1d=512
dense_1=256
Model4
Conv1d=256
dense_1=256
dense_2=128
Model0
Conv1d=512
dense_1=512
dense_2=256
Model1
Conv1d=1028
dense_1=1028
dense_2=512
Model2
Conv1d=512
dense_1=1028
dense_2=512
Model3
Conv1d=512
dense_1=512
dense_2=128
Model5

Conclusion

I.In our simulation,the model3 and model5 have highest accuracy rate in 6 different models.

II.In future, we can try more different model to find the more high accuracy rate of model. Regrettably, there is no rule and precise theory to build the model which has absolute highest accuracy rate.

III.We used the CNN layer as our first layer to achieve to classify the species of leaf, and the model we build has approximately 97.47%~98.99% accuracy rate.