IC HW5

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Problem 1

Original Setup

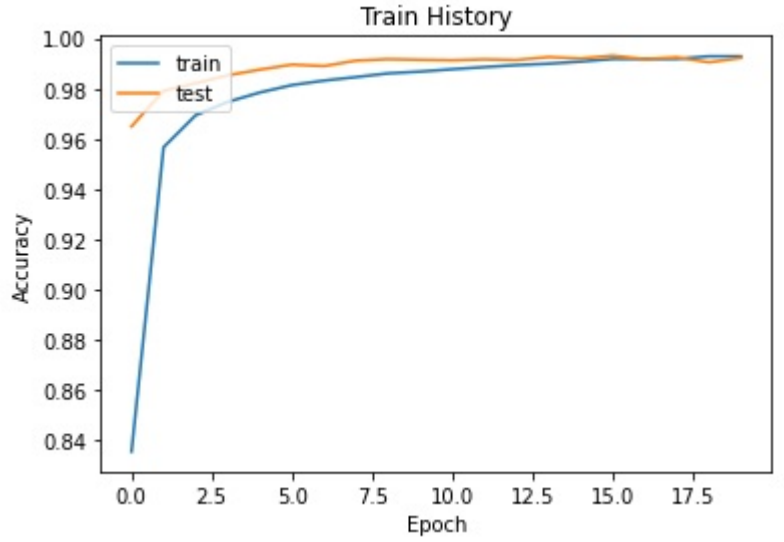
Model

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 16)        416

 max_pooling2d (MaxPooling2D  (None, 14, 14, 16)       0
 )

 conv2d_1 (Conv2D)           (None, 14, 14, 36)        14436

 max_pooling2d_1 (MaxPooling  (None, 7, 7, 36)         0
 2D)

 dropout (Dropout)           (None, 7, 7, 36)          0

 flatten (Flatten)           (None, 1764)              0

 dense (Dense)               (None, 128)               225920

 dropout_1 (Dropout)         (None, 128)               0

 dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 242,062
Trainable params: 242,062
Non-trainable params: 0
_________________________________________________________________
None
```

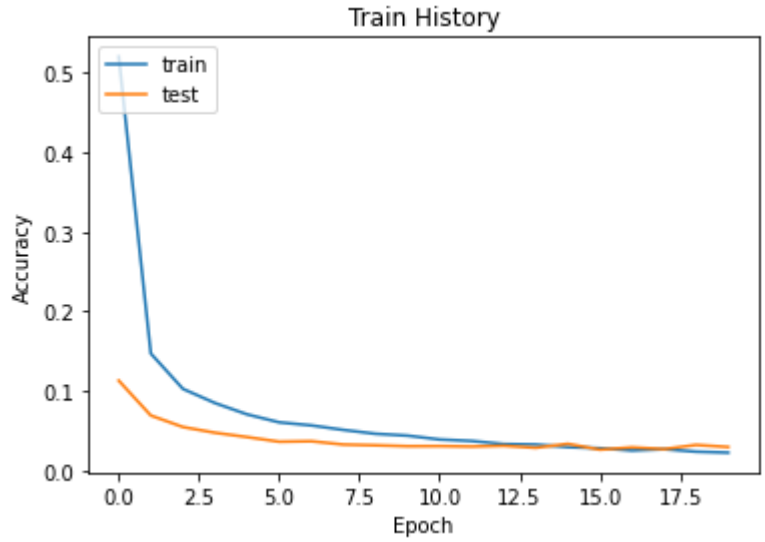
Hyperparameter

Item	Value
Optimizer	Adam
validation_split	0.2
epochs	20
batch_size	300

Accuracy Train History



Loss Train History



Test Accuracy

0.9919999837875366

Confusion Matrix

label	0	1	2	3	4	5	6	7	8	9
0	975	0	1	0	0	1	1	1	1	0
1	0	1129	0	2	0	0	0	3	1	0
2	0	0	1025	0	0	0	0	6	1	0
3	0	0	1	1006	0	1	0	0	2	0
4	0	0	0	0	980	0	1	0	0	1
5	2	0	0	8	0	880	1	0	0	1

label	0	1	2	3	4	5	6	7	8	9
6	3	2	1	0	2	2	945	0	3	0
7	0	1	1	1	0	0	0	1023	1	1
8	3	0	2	0	0	0	0	0	968	1
9	0	1	1	1	10	4	0	3	2	987

Modified Setup

- Replacing all "relu" activation with "elu" could increase accuracy to 0.9933.
- Adding another hidden layer with 64 unit doesn't seems to help.
- Reducing dropout rate also has no positive effect.

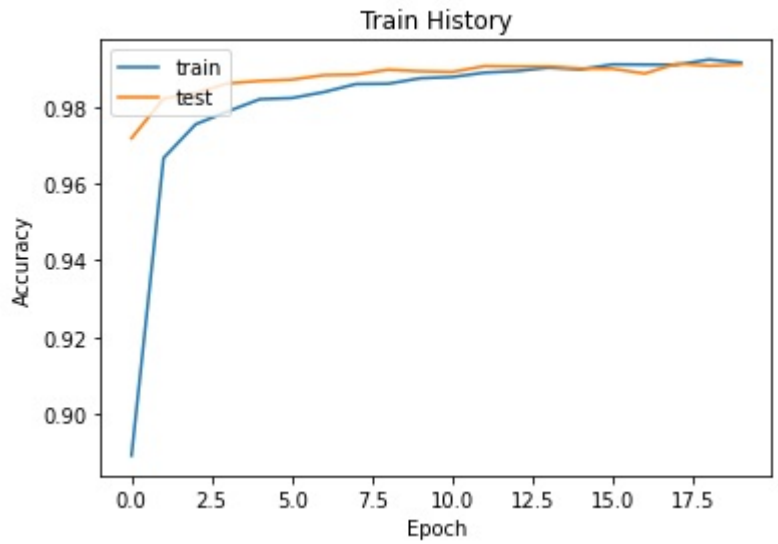
Model

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 16)        416

 max_pooling2d (MaxPooling2D  (None, 14, 14, 16)       0
 )

 conv2d_1 (Conv2D)           (None, 14, 14, 36)        14436

 max_pooling2d_1 (MaxPooling  (None, 7, 7, 36)         0
 2D)

 dropout (Dropout)           (None, 7, 7, 36)          0

 flatten (Flatten)           (None, 1764)              0

 dense (Dense)               (None, 128)               225920

 dropout_1 (Dropout)         (None, 128)               0

 dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 242,062
Trainable params: 242,062
Non-trainable params: 0
_________________________________________________________________
None
```

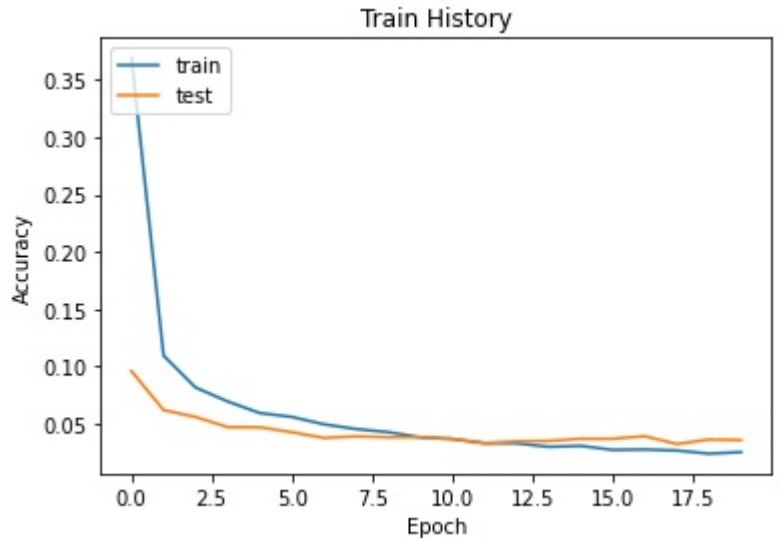
Hyperparameter

Item	Value
Optimizer	Adam
validation_split	0.2
epochs	20
batch_size	300

Accuracy Train History



Loss Train History



Test Accuracy

0.9933000206947327

Confusion Matrix

label	0	1	2	3	4	5	6	7	8	9
0	9	65	248	1	33	62	6	550	0	6
1	0	1114	0	0	0	4	0	17	0	0
2	0	40	875	8	0	1	0	108	0	0
3	0	0	0	988	0	7	0	15	0	0
4	0	9	1	0	773	1	0	190	0	8

label	0	1	2	3	4	5	6	7	8	9
5	0	0	1	5	0	883	0	1	0	2
6	0	10	6	0	3	167	769	3	0	0
7	0	0	0	0	0	0	0	1028	0	0
8	0	40	26	152	22	255	0	383	60	36
9	0	0	2	4	1	20	0	115	20	867

Problem 2

Original Setup

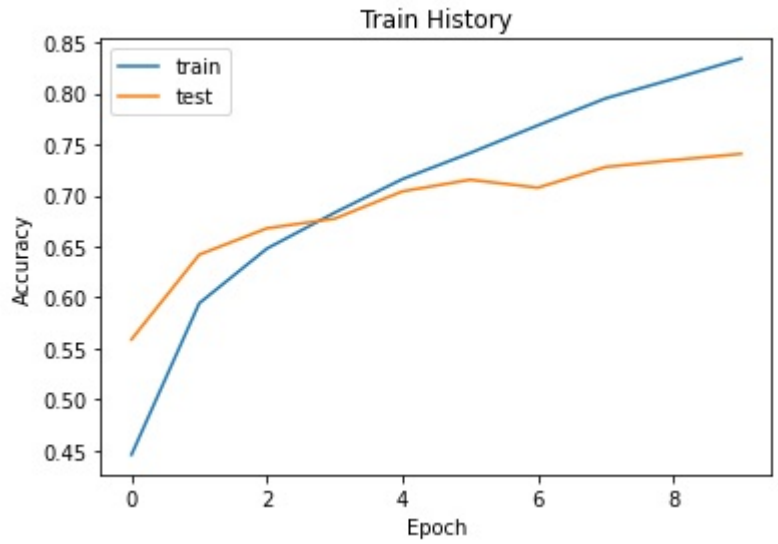
Model

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 32, 32, 32)        896

 dropout (Dropout)           (None, 32, 32, 32)        0

 max_pooling2d (MaxPooling2D  (None, 16, 16, 32)       0
 )

 conv2d_1 (Conv2D)           (None, 16, 16, 64)        18496

 dropout_1 (Dropout)         (None, 16, 16, 64)        0

 max_pooling2d_1 (MaxPooling  (None, 8, 8, 64)         0
 2D)

 flatten (Flatten)           (None, 4096)              0

 dropout_2 (Dropout)         (None, 4096)              0

 dense (Dense)               (None, 1024)              4195328

 dropout_3 (Dropout)         (None, 1024)              0

 dense_1 (Dense)             (None, 10)                10250

=================================================================
Total params: 4,224,970
Trainable params: 4,224,970
Non-trainable params: 0
_________________________________________________________________
None
```

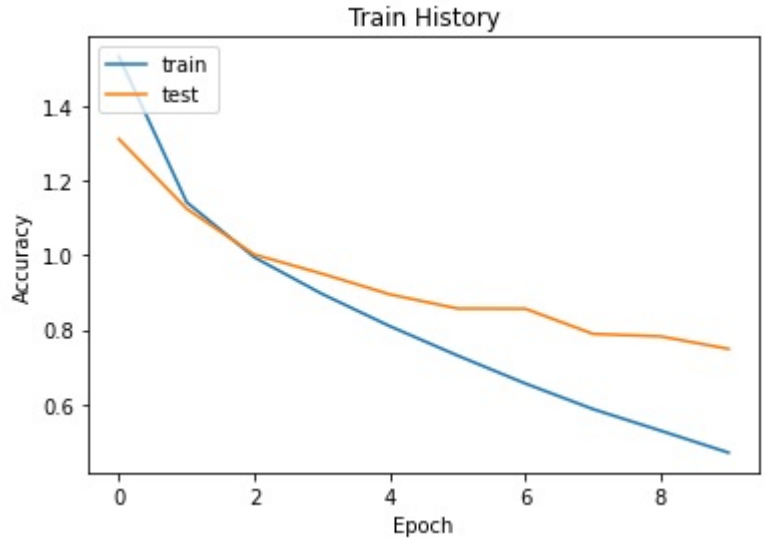
Hyperparameter

Item	Value
Optimize	Adam
validation_split	0.2
epochs	10
batch_size	128

Accuracy Train History



Loss Train History



Test Accuracy

0.7432000041007996

Confusion Matrix

label	0	1	2	3	4	5	6	7	8	9
0	749	14	54	14	10	9	13	8	91	38
1	11	848	13	6	4	5	10	2	32	69
2	57	3	701	37	86	33	49	16	10	8
3	18	9	102	523	81	160	54	20	22	11
4	16	3	89	54	742	18	33	32	12	1
5	12	1	79	165	65	609	24	36	8	1
6	2	4	59	46	36	20	823	1	8	1
7	15	3	51	27	70	46	9	766	5	8
8	38	17	25	6	10	9	5	1	872	17
9	21	71	15	13	6	13	9	13	40	799

Modified Setup

- Change Model structure.
- Data augmentation, including rotation, flip, shift and zoom.
- Train for more epochs.

Model

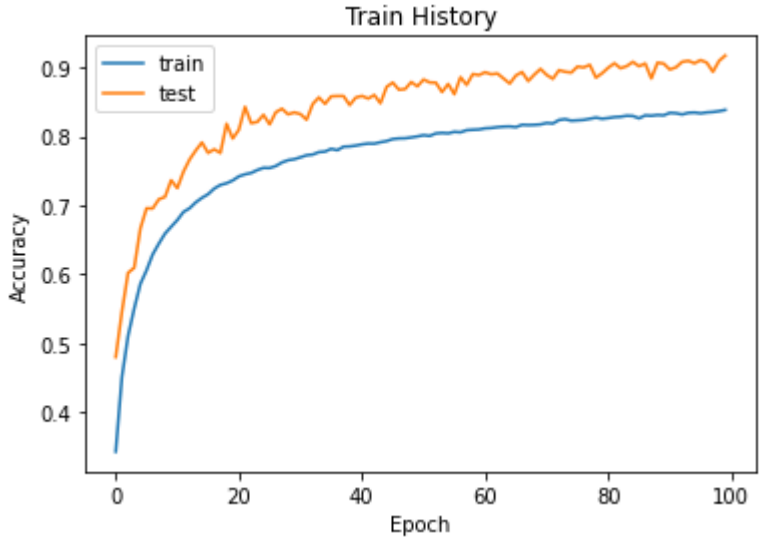
```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896

batch_normalization (BatchN  (None, 32, 32, 32)        128
ormalization)

conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248

batch_normalization_1 (Batc  (None, 32, 32, 32)        128
hNormalization)

max_pooling2d (MaxPooling2D  (None, 16, 16, 32)        0
)

dropout (Dropout)            (None, 16, 16, 32)        0

conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496

batch_normalization_2 (Batc  (None, 16, 16, 64)        256
hNormalization)

conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928

batch_normalization_3 (Batc  (None, 16, 16, 64)        256
hNormalization)
```

```
max_pooling2d_1 (MaxPooling  (None, 8, 8, 64)         0
2D)

dropout_1 (Dropout)          (None, 8, 8, 64)         0

conv2d_4 (Conv2D)            (None, 8, 8, 128)        73856

batch_normalization_4 (Batc  (None, 8, 8, 128)        512
hNormalization)

conv2d_5 (Conv2D)            (None, 8, 8, 128)        147584

batch_normalization_5 (Batc  (None, 8, 8, 128)        512
hNormalization)

max_pooling2d_2 (MaxPooling  (None, 4, 4, 128)        0
2D)

dropout_2 (Dropout)          (None, 4, 4, 128)        0

flatten (Flatten)            (None, 2048)             0

dense (Dense)                (None, 512)              1049088

batch_normalization_6 (Batc  (None, 512)              2048
hNormalization)

dropout_3 (Dropout)          (None, 512)              0

dense_1 (Dense)              (None, 10)               5130

=================================================================
Total params: 1,345,066
Trainable params: 1,343,146
Non-trainable params: 1,920
_________________________________________________________________
None
```

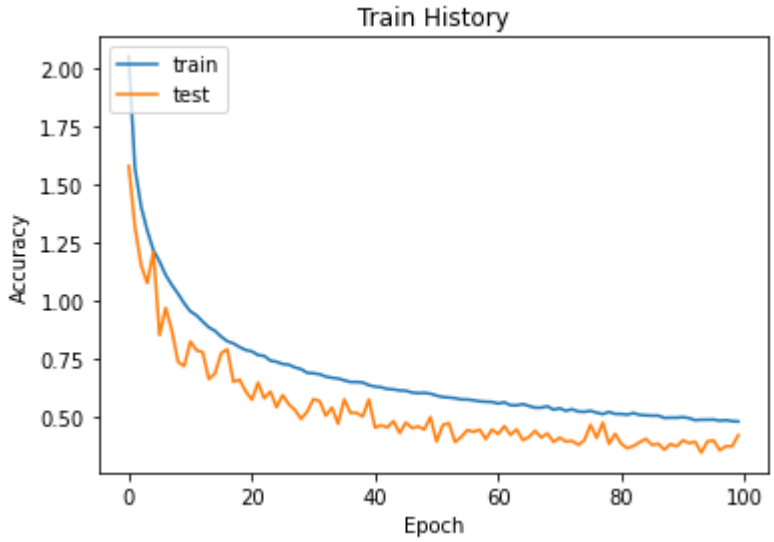
Hyperparameter

Item	Value
Optimize	Adam
validation_split	0.2
epochs	100
batch_size	128

Accuracy Train History



Loss Train History



Test Accuracy

0.8543000221252441

Confusion Matrix

label	0	1	2	3	4	5	6	7	8	9
0	870	25	7	10	6	0	4	8	17	53
1	2	944	0	1	0	0	0	0	1	52
2	56	9	750	35	39	13	54	19	3	22
3	7	10	23	747	25	53	54	22	11	48
4	7	2	29	16	842	8	40	44	2	10
5	7	6	15	115	18	734	43	25	5	32

label	0	1	2	3	4	5	6	7	8	9
6	4	6	7	9	8	1	945	3	3	14
7	9	7	7	12	14	15	8	896	2	30
8	49	41	4	1	1	0	4	0	865	35
9	5	39	0	0	1	1	1	1	2	950