TensorFlow 2 项目实战进阶

扫码试看/订阅

《TensorFlow 2 项目进阶实战》视频课程

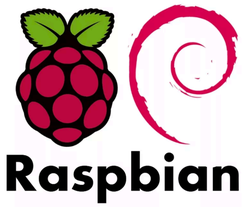
快速上手篇：动手训练模型和部署服务

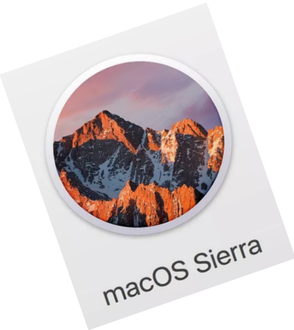
目录

TensorFlow 2 开发环境搭建

TensorFlow 2 支持的操作系统

- Python 3.5–3.7
- Ubuntu 16.04 or later
- Windows 7 or later
- macOS 10.12.6 (Sierra) or later (no GPU support)
- Raspbian 9.0 or later





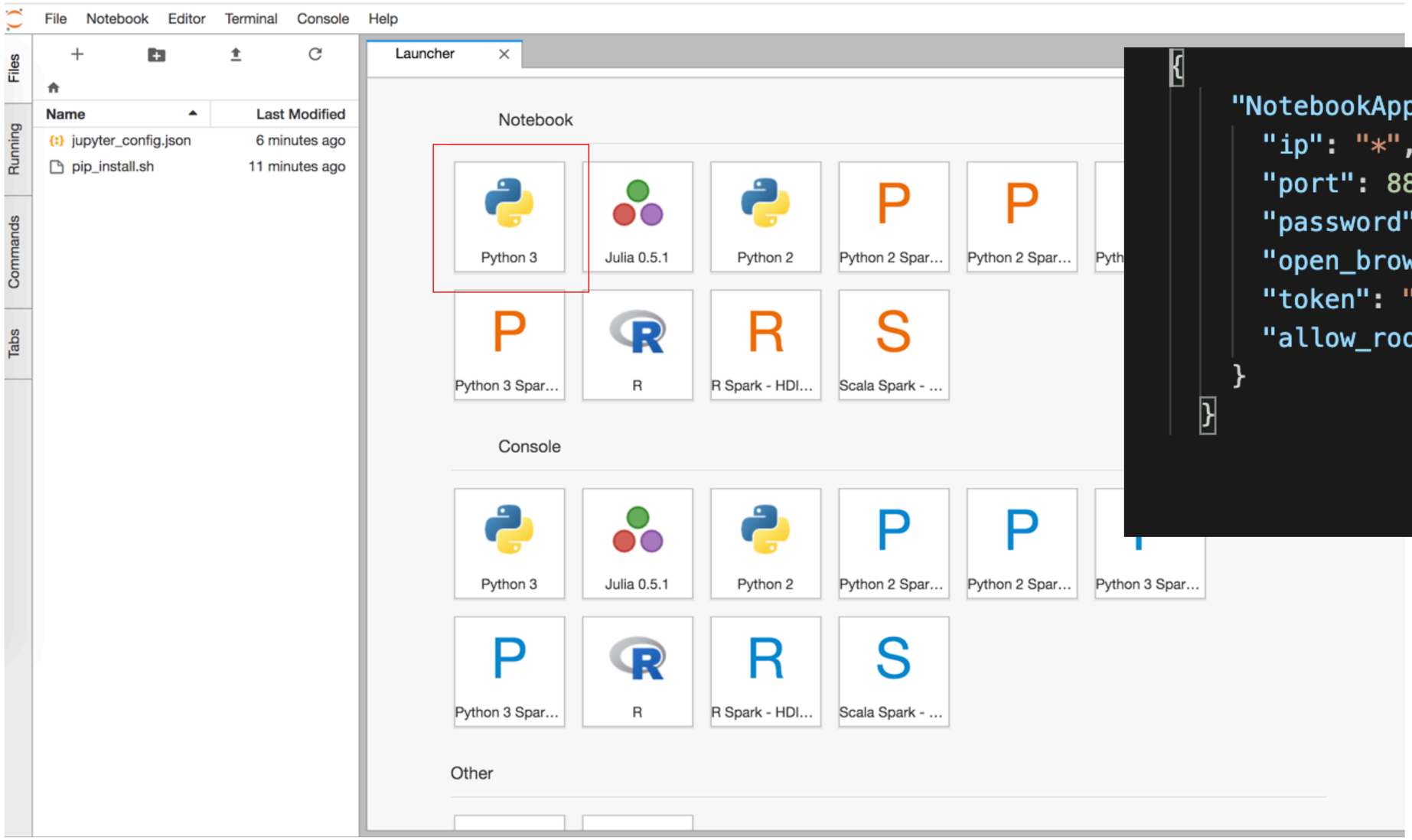
使用 pip3 安装 TensorFlow 2

```
# 更新 Pip
pip install -i https://mirrors.aliyun.com/pypi/simple --upgrade pip

# 安装 TensorFlow 2.2.0 RC4
pip install -i https://mirrors.aliyun.com/pypi/simple tensorflow==2.2.0rc4

# 安装 Jupyter Lab 作为交互式开发环境
pip install -i https://mirrors.aliyun.com/pypi/simple jupyter lab
```

在 Jupyter Lab 中使用 TensorFlow 2

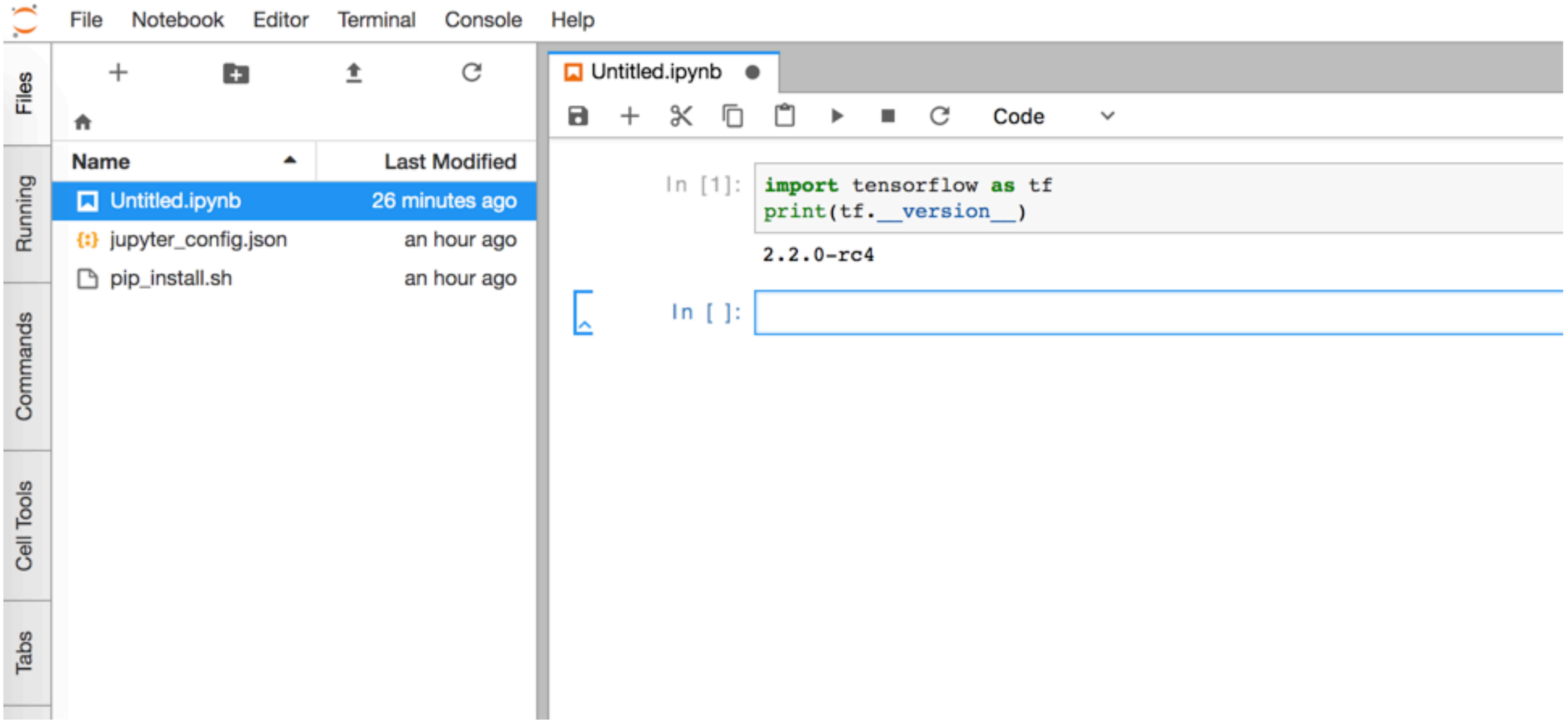
```
django@dev-tf2:~/advanced_practice/install$ jupyter lab --config jupyter_config.json
[W 05:08:55.656 LabApp] Config option `allow_root` not recognized by `LabApp`.  Did you mean one of: `allow_origin, allow_origin_pat`?
[W 05:08:55.662 LabApp] Config option `allow_root` not recognized by `LabApp`.  Did you mean one of: `allow_origin, allow_origin_pat`?
[W 05:08:55.788 LabApp] WARNING: The notebook server is listening on all IP addresses and not using encryption. This is not recommended.
[W 05:08:55.788 LabApp] WARNING: The notebook server is listening on all IP addresses and not using authentication. This is highly insecure and not recommended.
[W 05:08:55.793 LabApp] JupyterLab server extension not enabled, manually loading...
[I 05:08:55.793 LabApp] JupyterLab alpha preview extension loaded from /anaconda/envs/py35/lib/python3.5/site-packages/jupyterlab
JupyterLab v0.26.4
Known labextensions:
[I 05:08:55.794 LabApp] Running the core application with no additional extensions or settings
[E 05:08:55.795 LabApp] shemas_dir: /anaconda/envs/py35/lib/python3.5/site-packages/jupyterlab/schemas
[I 05:08:55.797 LabApp] Serving notebooks from local directory: /home/django/advanced_practice/install
[I 05:08:55.798 LabApp] 0 active kernels
[I 05:08:55.798 LabApp] The Jupyter Notebook is running at: http://[all ip addresses on your system]:8888/
[I 05:08:55.798 LabApp] Use Control-C to stop this server and shut down all kernels (twice to skip confirmation).
```

在 Jupyter Lab 中使用 TensorFlow 2

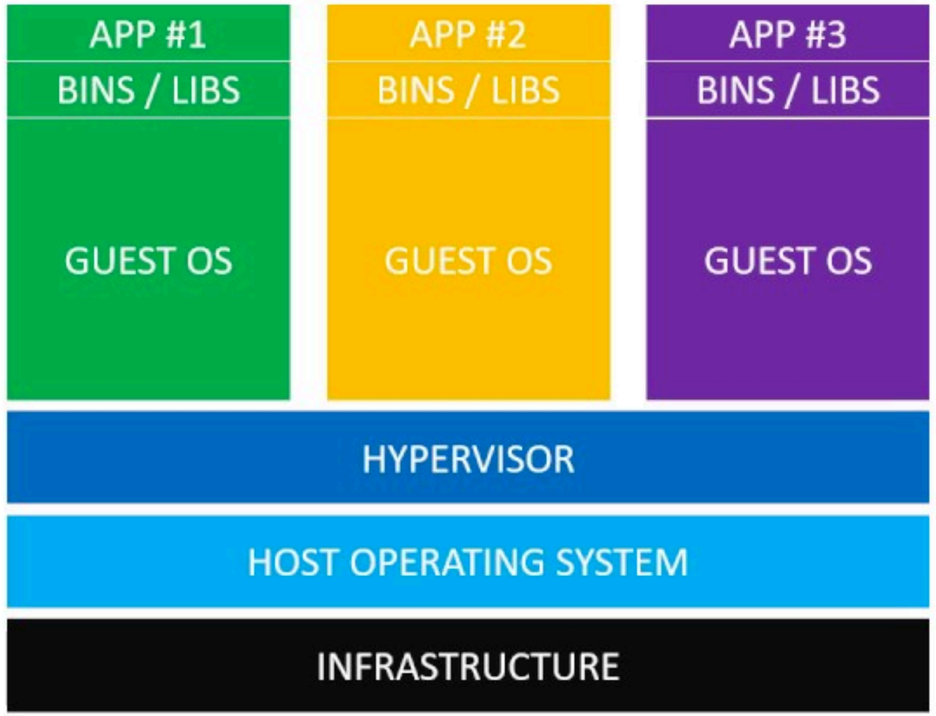



```
{
    "NotebookApp": {
      "ip": "*",
      "port": 8888,
      "password": "",
      "open_browser": false,
      "token": "",
      "allow_root": true
    }
}
```

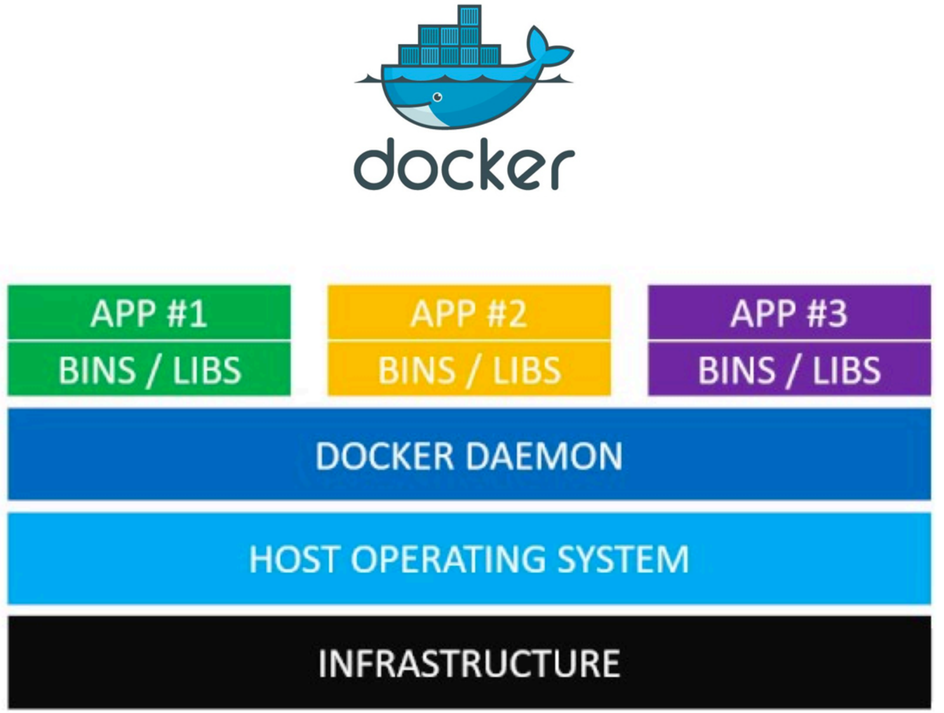
在 Jupyter Lab 中使用 TensorFlow 2



Docker 容器 与 虚拟机



虚拟机



Docker 容器

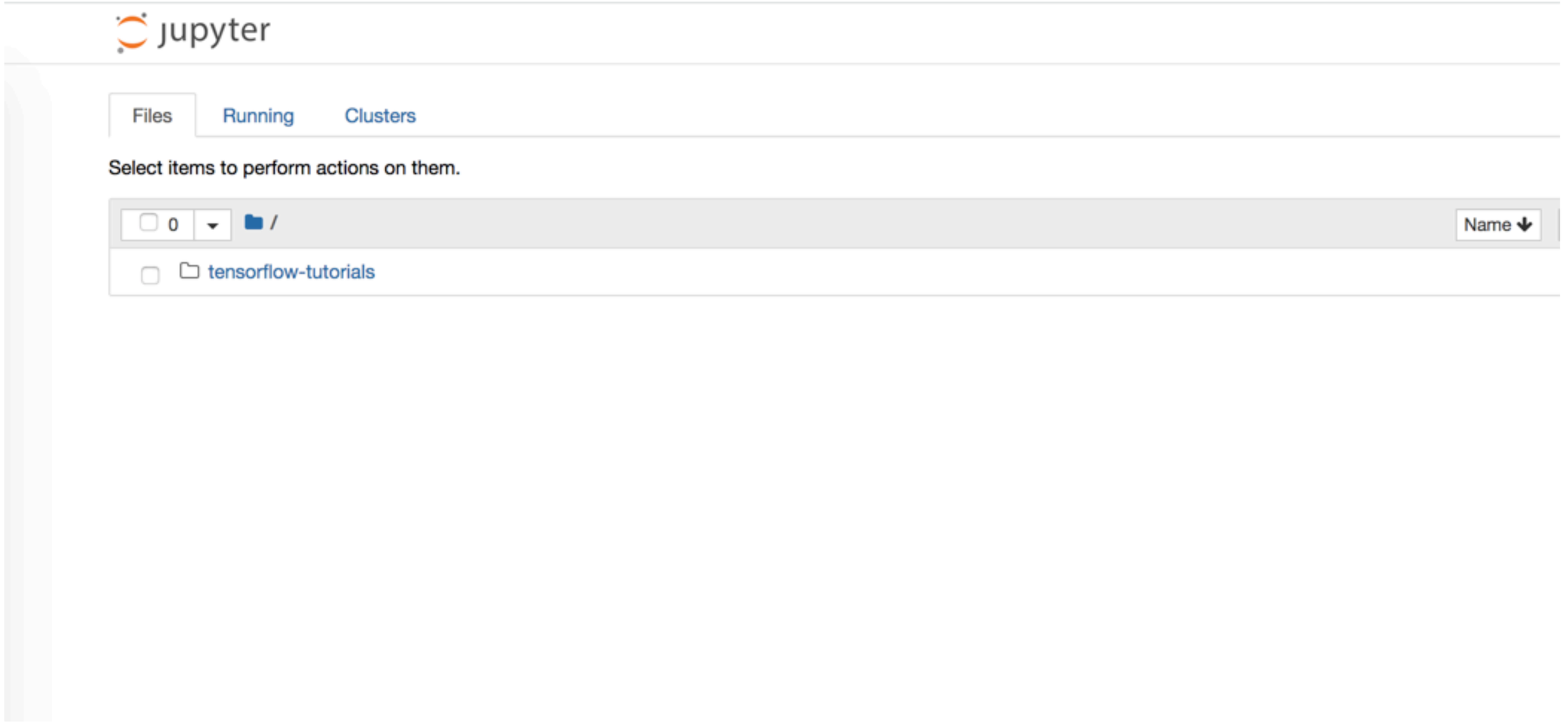
在 Docker 中使用 TensorFlow 2

```
django@dev-tf2:~/advanced_practice/instal$ sudo docker run -it -p 8888:8888 tensorflow/tensorflow:2.2.0rc4-jupyter
Unable to find image 'tensorflow/tensorflow:2.2.0rc4-jupyter' locally
2.2.0rc4-jupyter: Pulling from tensorflow/tensorflow
23884877105a: Pulling fs layer
bc38caa0f5b9: Pulling fs layer
2910811b6c42: Pulling fs layer
36505266dcc6: Waiting
49b62c208964: Waiting
0eed2e253368: Waiting
6e96dc8601eb: Waiting
2e7d0b5b1540: Waiting
f65c844bdd2c: Waiting
3c7423a0cd91: Waiting
282930c7512c: Waiting
3534c13b42db: Waiting
438a44c74bf6: Waiting
928f5c4a2608: Waiting
c541daaabd98: Waiting
441ce73ef16d: Waiting
845b44a04597: Waiting
df3ec2d4217e: Waiting
e6cad6aee343: Waiting
60d86d9f0b2d: Waiting
db44bb841228: Waiting
55f54a4d310e: Waiting
92d8c786052e: Waiting
bf1e2d268bc4: Waiting
0b5f6d50dead: Waiting
e6ca097c0aa9: Waiting
8d98b4a61ef7: Waiting
```

在 Docker 中使用 TensorFlow 2

```
Digest: sha256:b08518e183be034c99de228310f5f506af2e2ce369323ee5994447d29a537019
Status: Downloaded newer image for tensorflow/tensorflow:2.2.0rc4-jupyter
[I 05:20:07.286 NotebookApp] Writing notebook server cookie secret to /root/.local/share/jupyter/runtime/notebook_cookie_secret
jupyter_http_over_ws extension initialized. Listening on /http_over_websocket
[I 05:20:07.549 NotebookApp] Serving notebooks from local directory: /tf
[I 05:20:07.550 NotebookApp] The Jupyter Notebook is running at:
[I 05:20:07.550 NotebookApp] http://0005478527d6:8888/?token=51a44dbd0904acb48e8a65dd678c79f4b6885a066bc978c2
[I 05:20:07.550 NotebookApp]  or http://127.0.0.1:8888/?token=51a44dbd0904acb48e8a65dd678c79f4b6885a066bc978c2
[I 05:20:07.550 NotebookApp] Use Control-C to stop this server and shut down all kernels (twice to skip confirmation).
[C 05:20:07.554 NotebookApp]

    To access the notebook, open this file in a browser:
        file:///root/.local/share/jupyter/runtime/nbserver-1-open.html
    Or copy and paste one of these URLs:
        http://0005478527d6:8888/?token=51a44dbd0904acb48e8a65dd678c79f4b6885a066bc978c2
     or http://127.0.0.1:8888/?token=51a44dbd0904acb48e8a65dd678c79f4b6885a066bc978c2
[W 05:20:09.483 NotebookApp] Forbidden
[W 05:20:09.483 NotebookApp] 403 GET /api/contents/?content=1&1588569609412 (58.247.11.58) 1.36ms referer=http://139.219.130.157:8888/lab?
[W 05:20:13.398 NotebookApp] Forbidden
[W 05:20:13.398 NotebookApp] 403 GET /api/kernelspecs?1588569613362 (58.247.11.58) 1.39ms referer=http://139.219.130.157:8888/lab?
[W 05:20:15.375 NotebookApp] Forbidden
[W 05:20:15.376 NotebookApp] 403 GET /api/sessions?1588569615271 (58.247.11.58) 0.99ms referer=http://139.219.130.157:8888/lab?
[W 05:20:15.383 NotebookApp] Forbidden
[W 05:20:15.383 NotebookApp] 403 GET /api/terminals?1588569615272 (58.247.11.58) 0.75ms referer=http://139.219.130.157:8888/lab?
[W 05:20:19.566 NotebookApp] Forbidden
[W 05:20:19.567 NotebookApp] 403 GET /api/contents/?content=1&1588569619447 (58.247.11.58) 1.02ms referer=http://139.219.130.157:8888/lab?
[W 05:20:25.341 NotebookApp] Forbidden
```

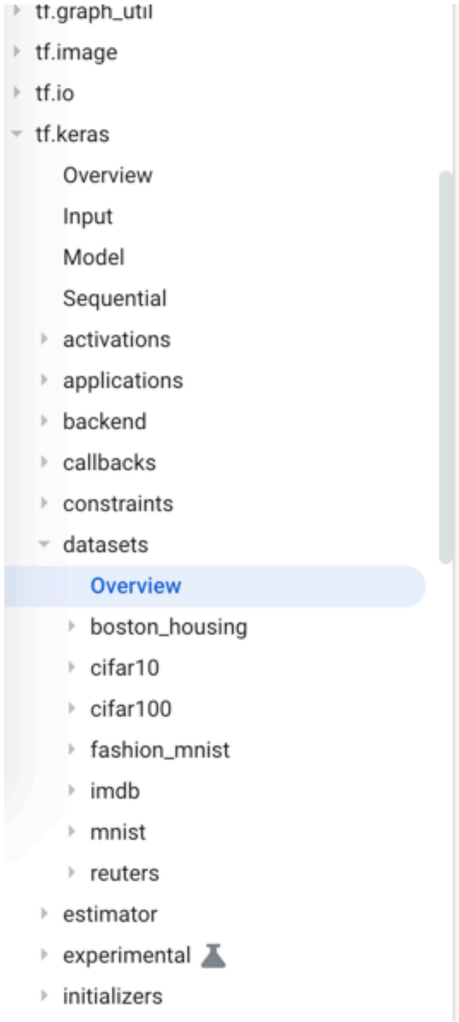
在 Docker 中使用 TensorFlow 2



Try it!

使用 tf.keras.datasets 加载数据

使用 tf.keras.datasets 预置数据集



Module: tf.keras.datasets

TensorFlow 1 version

Public API for tf.keras.datasets namespace.

Modules

`boston_housing` module: Boston housing price regression dataset.

`cifar10` module: CIFAR10 small images classification dataset.

`cifar100` module: CIFAR100 small images classification dataset.

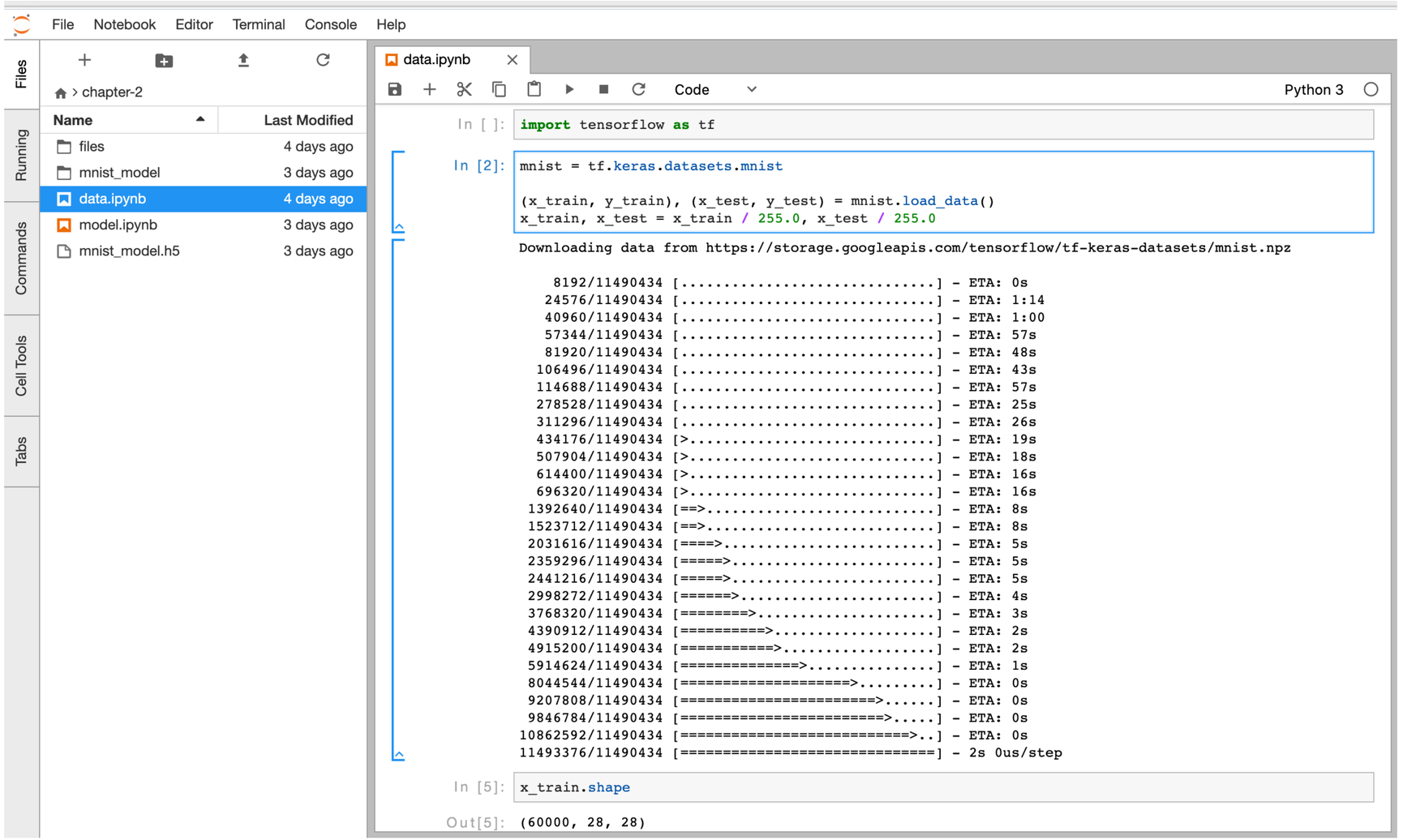
`fashion_mnist` module: Fashion-MNIST dataset.

`imdb` module: IMDB sentiment classification dataset.

`mnist` module: MNIST handwritten digits dataset.

`reuters` module: Reuters topic classification dataset.

使用 tf.keras.datasets.mnist 数据集



使用 tf.keras.datasets.mnist 数据集

File Notebook Editor Terminal Console Help

Files Running Commands Cell Tools Tabs

chapter-2

Name	Last Modified
files	4 days ago
mnist_model	3 days ago
data.ipynb	4 days ago
model.ipynb	3 days ago
mnist_model.h5	3 days ago

data.ipynb

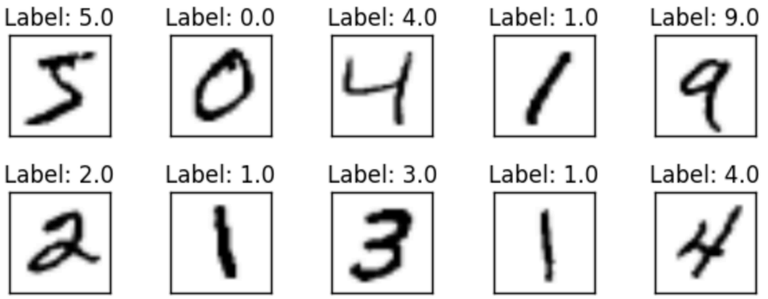
Code Python 3

In [6]:
```
y_train = y_train.astype('float32')
y_test = y_test.astype('float32')

# Reserve 10,000 samples for validation
x_val = x_train[-10000:]
y_val = y_train[-10000:]
x_train = x_train[:-10000]
y_train = y_train[:-10000]
```

In [7]:
```
print(x_train.shape)
print(x_val.shape)
```

```
(50000, 28, 28)
(10000, 28, 28)
```

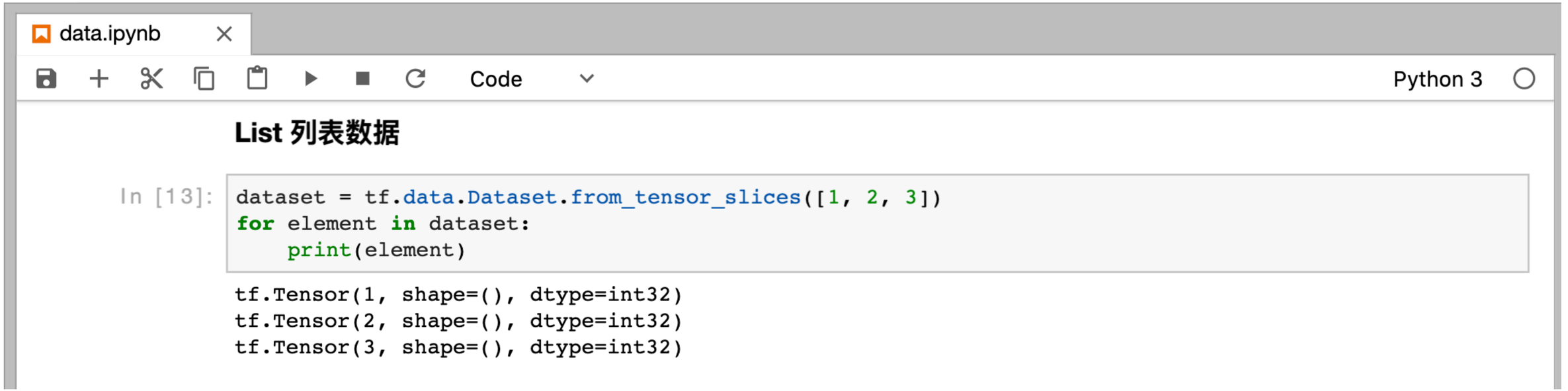
In [12]:
```
%matplotlib inline

import matplotlib.pyplot as plt

fig = plt.figure()
for i in range(15):
    plt.subplot(3,5,i+1) # 绘制前15个手写体数字，以3行5列子图形式展示
    plt.tight_layout() # 自动适配子图尺寸
    plt.imshow(x_train[i], cmap='Greys') # 使用灰色显示像素灰度值
    plt.title("Label: {}".format(y_train[i])) # 设置标签为子图标题
    plt.xticks([]) # 删除x轴标记
    plt.yticks([]) # 删除y轴标记
```



Try it!

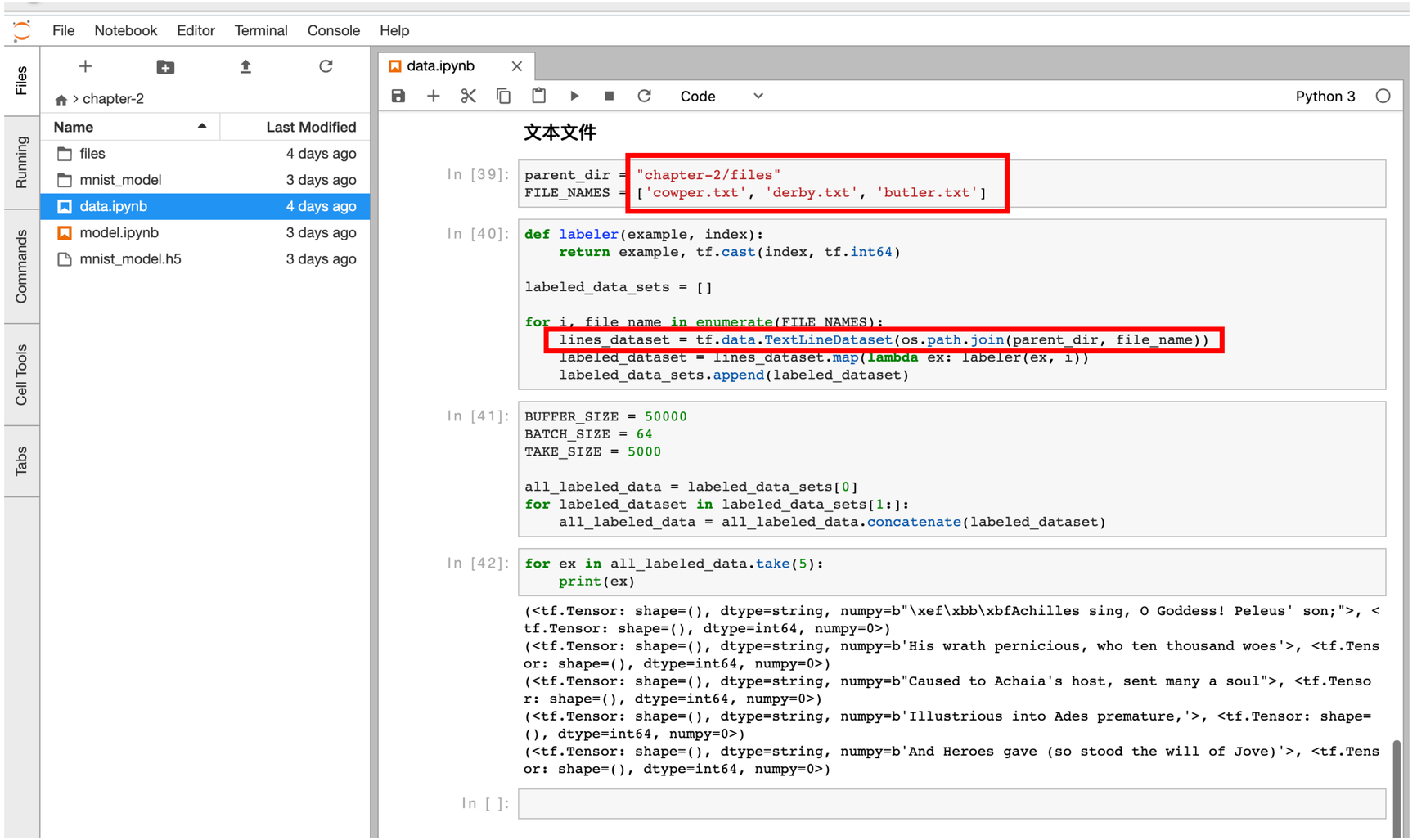
使用 tf.data.Dataset 加载数据

使用 tf.data.Dataset.from_tensor_slices 加载 List



使用 tf.data.Dataset.from_generator 加载 Generator

使用 tf.data.TextLineDataset 加载文本



Try it!

使用 tf.keras.Model 管理模型

历史上的 tf.keras.Model

- Class tf.compat.v1.keras.Model
- Class tf.compat.v1.keras.models.Model
- Class tf.compat.v2.keras.Model
- Class tf.compat.v2.keras.models.Model
- Class tf.keras.models.Model

使用 tf.keras.Model 构建模型

构建CNN模型网络（Sequential）

In [3]:
```
model = tf.keras.models.Sequential([
  tf.keras.layers.Flatten(input_shape=(28, 28)),
  tf.keras.layers.Dense(128, activation='relu'),
  tf.keras.layers.Dropout(0.2),
  tf.keras.layers.Dense(10)
])
```

使用 tf.keras.Model 构建模型

构建CNN模型网络（Functional API）

In [1]:
```
import tensorflow as tf

inputs = tf.keras.Input(shape=(3,))
x = tf.keras.layers.Dense(4, activation=tf.nn.relu)(inputs)
outputs = tf.keras.layers.Dense(5, activation=tf.nn.softmax)(x)
model = tf.keras.Model(inputs=inputs, outputs=outputs)
```

使用 tf.keras.Model 训练模型

In [4]:
```
model.compile(optimizer='adam',
              loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),
              metrics=['accuracy'])
```

In [5]:
```
model.fit(x_train, y_train, epochs=5)
```

```
Epoch 1/5

   1/1875 [..............................] - ETA: 0s - accuracy: 0.0000e+00 - loss: 2.4046
  32/1875 [..............................] - ETA: 2s - accuracy: 0.5342 - loss: 1.5983
  63/1875 [>.............................] - ETA: 2s - accuracy: 0.6607 - loss: 1.1938
  95/1875 [>.............................] - ETA: 2s - accuracy: 0.7135 - loss: 0.9955
 126/1875 [=>............................] - ETA: 2s - accuracy: 0.7490 - loss: 0.8747
 157/1875 [=>............................] - ETA: 2s - accuracy: 0.7721 - loss: 0.7990
 187/1875 [=>............................] - ETA: 2s - accuracy: 0.7884 - loss: 0.7420
 219/1875 [==>...........................] - ETA: 2s - accuracy: 0.8024 - loss: 0.6890
 251/1875 [===>..........................] - ETA: 2s - accuracy: 0.8141 - loss: 0.6492
 284/1875 [===>..........................] - ETA: 2s - accuracy: 0.8220 - loss: 0.6184
 316/1875 [====>.........................] - ETA: 2s - accuracy: 0.8288 - loss: 0.5947
 348/1875 [====>.........................] - ETA: 2s - accuracy: 0.8351 - loss: 0.5712
 380/1875 [=====>........................] - ETA: 2s - accuracy: 0.8406 - loss: 0.5505
 411/1875 [=====>........................] - ETA: 2s - accuracy: 0.8451 - loss: 0.5323
 444/1875 [======>.......................] - ETA: 2s - accuracy: 0.8483 - loss: 0.5185
 475/1875 [======>.......................] - ETA: 2s - accuracy: 0.8517 - loss: 0.5061
 506/1875 [=======>......................] - ETA: 2s - accuracy: 0.8557 - loss: 0.4933
 537/1875 [=======>......................] - ETA: 2s - accuracy: 0.8593 - loss: 0.4819
 569/1875 [========>.....................] - ETA: 2s - accuracy: 0.8628 - loss: 0.4706
 600/1875 [========>.....................] - ETA: 2s - accuracy: 0.8659 - loss: 0.4595
 632/1875 [=========>....................] - ETA: 1s - accuracy: 0.8687 - loss: 0.4487
 663/1875 [=========>....................] - ETA: 1s - accuracy: 0.8711 - loss: 0.4407
 695/1875 [==========>...................] - ETA: 1s - accuracy: 0.8733 - loss: 0.4330
 727/1875 [==========>...................] - ETA: 1s - accuracy: 0.8753 - loss: 0.4251
 758/1875 [===========>..................] - ETA: 1s - accuracy: 0.8776 - loss: 0.4182
 790/1875 [===========>..................] - ETA: 1s - accuracy: 0.8799 - loss: 0.4109
 817/1875 [============>.................] - ETA: 1s - accuracy: 0.8814 - loss: 0.4059
 851/1875 [============>.................] - ETA: 1s - accuracy: 0.8832 - loss: 0.3986
 885/1875 [=============>................] - ETA: 1s - accuracy: 0.8843 - loss: 0.3941
```

保存和加载 h5 模型

保存为 h5 模型

In [11]:
```
model.save("mnist_model.h5")
```

加载 h5 模型

In [15]:
```
h5_model = tf.keras.models.load_model("mnist_model.h5")
```

In [16]:
```
h5_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
flatten (Flatten)            (None, 784)               0
_________________________________________________________________
dense (Dense)                (None, 128)               100480
_________________________________________________________________
dropout (Dropout)            (None, 128)               0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                1290
=================================================================
Total params: 101,770
Trainable params: 101,770
Non-trainable params: 0
_________________________________________________________________
```

保存和加载 SavedModel 模型

保存为 SavedModel 模型

In [17]:
```
model.save("mnist_model")
```

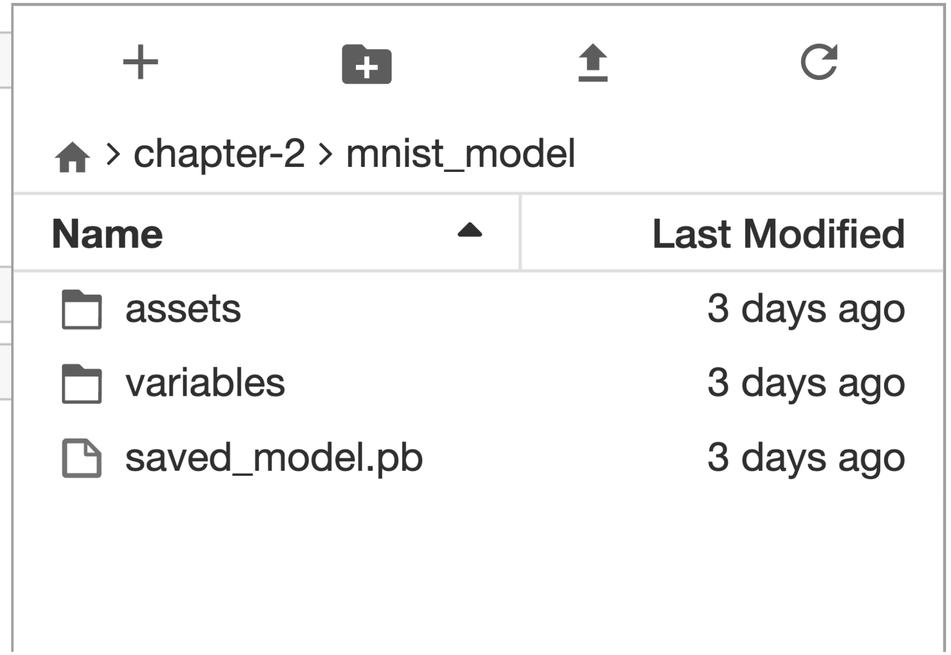
```
INFO:tensorflow:Assets written to: mnist_model/assets
```

加载 SavedModel 模型

In [18]:
```
sm_model = tf.keras.models.load_model("mnist_model.h5")
```

In [19]:
```
sm_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
flatten (Flatten)            (None, 784)               0
_________________________________________________________________
dense (Dense)                (None, 128)               100480
_________________________________________________________________
dropout (Dropout)            (None, 128)               0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                1290
=================================================================
Total params: 101,770
Trainable params: 101,770
Non-trainable params: 0
_________________________________________________________________
```



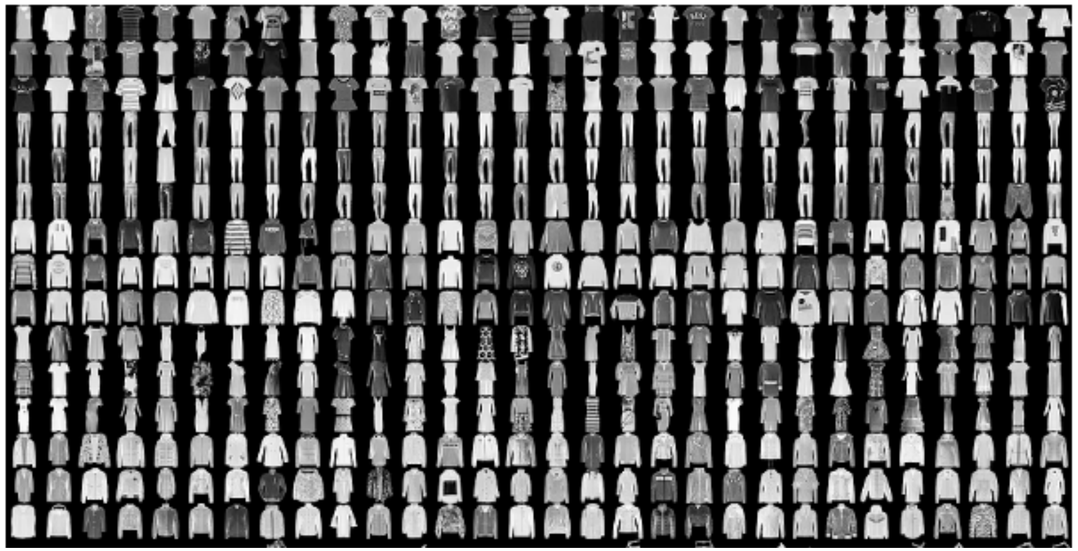
Fashion MNIST 数据集介绍

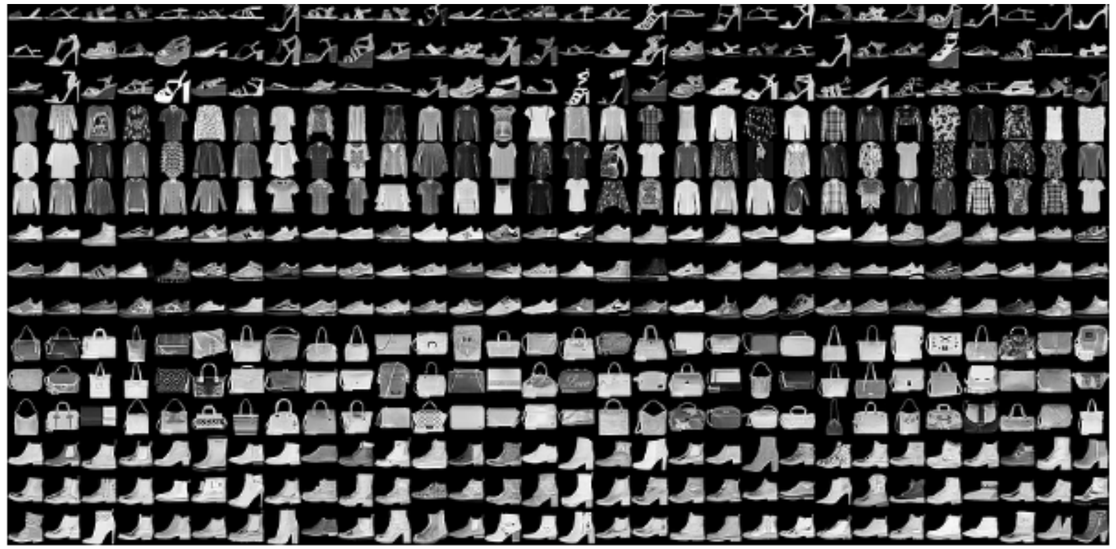
Original MNIST dataset

The MNIST database of handwritten digits, available from this page, has a training set of 60,000 examples, and a test set of 10,000 examples. It is a subset of a larger set available from NIST. The digits have been size-normalized and centered in a fixed-size image.

Fashion MNIST dataset

This guide uses the Fashion MNIST dataset which contains 70,000 grayscale images in 10 categories. The images show individual articles of clothing at low resolution (28 by 28 pixels). https://github.com/zalandoresearch/fashion-mnist





Why we need Fashion MNIST

The original MNIST dataset contains a lot of handwritten digits. Members of the AI/ML/Data Science community love this dataset and use it as a benchmark to validate their algorithms. In fact, MNIST is often the first dataset researchers try. *"If it doesn't work on MNIST, it **won't work** at all"*, they said. *"Well, if it does work on MNIST, it may still fail on others."*

To Serious Machine Learning Researchers

Seriously, we are talking about replacing MNIST. Here are some good reasons:

- **MNIST is too easy.** Convolutional nets can achieve 99.7% on MNIST. Classic machine learning algorithms can also achieve 97% easily. Check out our side-by-side benchmark for Fashion-MNIST vs. MNIST, and read "Most pairs of MNIST digits can be distinguished pretty well by just one pixel."
- **MNIST is overused.** In this April 2017 Twitter thread, Google Brain research scientist and deep learning expert Ian Goodfellow calls for people to move away from MNIST.
- **MNIST can not represent modern CV tasks**, as noted in this April 2017 Twitter thread, deep learning expert/Keras author François Chollet.

Benchmark on original MNIST

zalando research | Benchmark | Fashion MNIST | Original MNIST | Side-by-Side | Repository

Filter 129 results by Name, Parameter

Name	Parameter	Accuracy (mean)	Accuracy (std)	Training time	Repeats	Job start	Job Done
SVC	{"C":100,"kernel":"poly"}	0.978	0.000	1:08:41	2	3 years ago	3 years ago
SVC	{"C":10,"kernel":"poly"}	0.976	0.000	1:15:29	2	3 years ago	3 years ago
SVC	{"C":10,"kernel":"rbf"}	0.973	0.000	0:48:32	2	3 years ago	3 years ago
MLPClassifier	{"activation":"relu","hidden_layer_sizes":[100]}	0.972	0.000	0:06:55	2	3 years ago	3 years ago
MLPClassifier	{"activation":"relu","hidden_layer_sizes":[100,10]}	0.972	0.001	0:06:41	2	3 years ago	3 years ago
SVC	{"C":100,"kernel":"rbf"}	0.972	0.000	0:53:50	2	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"gini","max_depth":50,"n_estimators":100}	0.971	0.001	0:03:23	2	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"gini","max_depth":100,"n_estimators":100}	0.970	0.001	0:03:19	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":100}	0.970	0.002	0:04:35	5	3 years ago	3 years ago
GradientBoostingClassifier	{"loss":"deviance","max_depth":10,"n_estimators":100}	0.969	0.001	14:04:48	2	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":50,"n_estimators":100}	0.969	0.002	0:03:54	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":50}	0.968	0.003	0:02:53	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"gini","max_depth":50,"n_estimators":50}	0.968	0.002	0:01:35	5	3 years ago	3 years ago

Benchmark on Fashion MNIST

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Filter 129 results by Name, Parameter

Name	Parameter	Accuracy (mean)	Accuracy (std)	Training time	Repeats	Job start	Job Done
SVC	{"C":10,"kernel":"poly"}	0.897	0.000	1:12:39	2	3 years ago	3 years ago
SVC	{"C":100,"kernel":"poly"}	0.896	0.000	1:12:30	2	3 years ago	3 years ago
SVC	{"C":10,"kernel":"rbf"}	0.896	0.000	1:15:25	2	3 years ago	3 years ago
SVC	{"C":100,"kernel":"rbf"}	0.893	0.000	1:18:01	2	3 years ago	3 years ago
GradientBoostingClassifier	{"loss":"deviance","max_depth":10,"n_estimators":100}	0.888	0.001	17:38:22	5	3 years ago	3 years ago
SVC	{"C":1,"kernel":"rbf"}	0.884	0.000	1:15:54	2	3 years ago	3 years ago
GradientBoostingClassifier	{"loss":"deviance","max_depth":10,"n_estimators":50}	0.880	0.001	16:42:47	2	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":50,"n_estimators":100}	0.879	0.000	0:08:39	2	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":100}	0.877	0.001	0:08:29	2	3 years ago	3 years ago
MLPClassifier	{"activation":"relu","hidden_layer_sizes":[100]}	0.877	0.005	0:16:03	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"gini","max_depth":100,"n_estimators":100}	0.876	0.002	0:05:48	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"gini","max_depth":50,"n_estimators":100}	0.876	0.003	0:09:55	5	3 years ago	3 years ago
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":50}	0.875	0.001	0:06:25	5	3 years ago	3 years ago

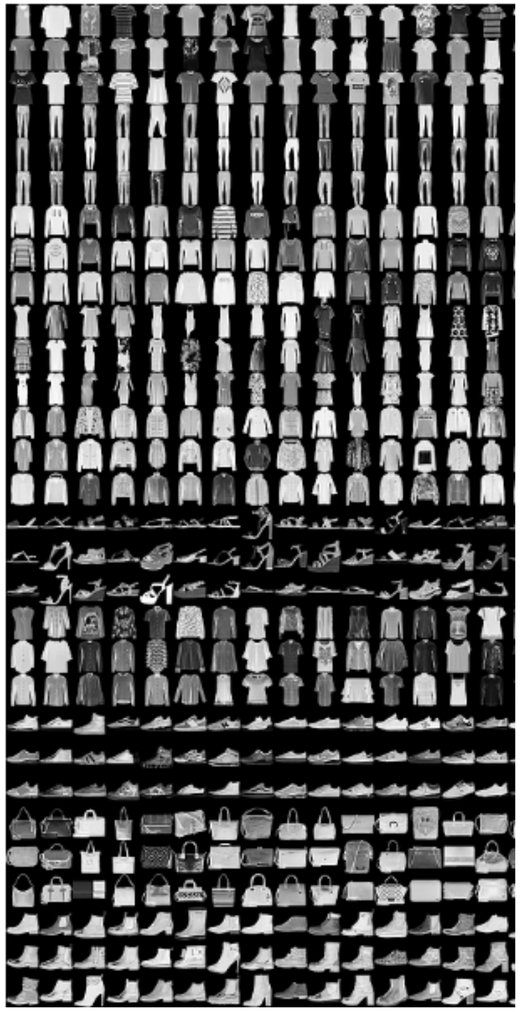
Benchmark Side-by-side

zalando research | Benchmark | Fashion MNIST | Original MNIST | Side-by-Side | Repository

Filter 129 results by Name, Parameter

Name	Parameter	Fashion Accuracy (mean)	MNIST Accuracy (mean)	Fashion Accuracy (std)	MNIST Accuracy (std)
SVC	{"C":10,"kernel":"poly"}	0.897	0.976	0.000	0.000
SVC	{"C":100,"kernel":"poly"}	0.896	0.978	0.000	0.000
SVC	{"C":10,"kernel":"rbf"}	0.896	0.973	0.000	0.000
SVC	{"C":100,"kernel":"rbf"}	0.893	0.972	0.000	0.000
GradientBoostingClassifier	{"loss":"deviance","max_depth":10,"n_estimators":100}	0.888	0.969	0.001	0.001
SVC	{"C":1,"kernel":"rbf"}	0.884	0.966	0.000	0.000
GradientBoostingClassifier	{"loss":"deviance","max_depth":10,"n_estimators":50}	0.880	0.964	0.001	0.003
RandomForestClassifier	{"criterion":"entropy","max_depth":50,"n_estimators":100}	0.879	0.969	0.000	0.002
MLPClassifier	{"activation":"relu","hidden_layer_sizes":[100]}	0.877	0.972	0.005	0.000
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":100}	0.877	0.970	0.001	0.002
RandomForestClassifier	{"criterion":"gini","max_depth":50,"n_estimators":100}	0.876	0.971	0.003	0.001
RandomForestClassifier	{"criterion":"gini","max_depth":100,"n_estimators":100}	0.876	0.970	0.002	0.001
RandomForestClassifier	{"criterion":"entropy","max_depth":100,"n_estimators":50}	0.875	0.968	0.001	0.003

Fashion MNIST dataset



Label	Description
0	T-shirt/top
1	Trouser
2	Pullover
3	Dress
4	Coat
5	Sandal
6	Shirt
7	Sneaker
8	Bag
9	Ankle boot

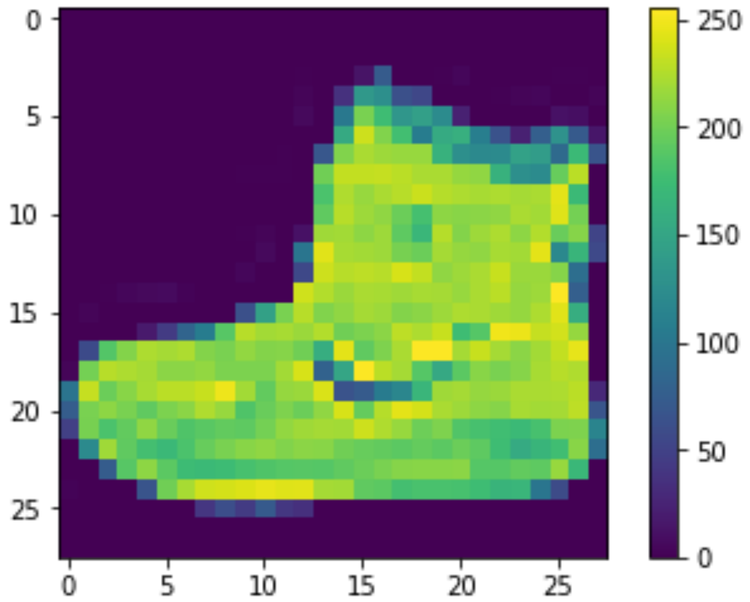
使用 TensorFlow 2 训练分类网络

Get Fashion MNIST dataset

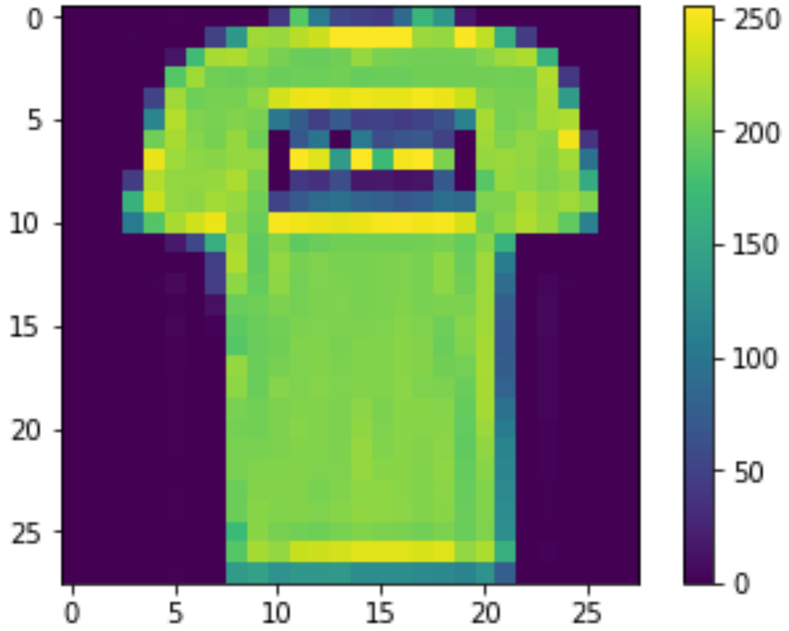
```
from  tensorflow I mport  keras

import  tensorflow  as  tf

fashion_mnist = keras.datasets.fashion_mnist

(train_images, train_labels), (test_images, test_labels)  =  fashion_mnist.load_data()
```

Preprocess data

```
import matplotlib.pyplot as plt
plt.figure()
plt.imshow(train_images[0])
plt.colorbar()
plt.grid(False)
plt.show()
```




```
import matplotlib.pyplot as plt
plt.figure()
plt.imshow(train_images[1])
plt.colorbar()
plt.grid(False)
plt.show()
```



Preprocess data

```
class_names = [ 'T-shirt/top', 'Trouser', 'Pullover', 'Dress', 'Coat',
                'Sandal', 'Shirt', 'Sneaker', 'Bag', 'Ankle boot' ]

train_images = train_images / 255.0
test_images = test_images / 255.0

plt.figure(figsize=(8, 8))
for i in range(25):
    plt.subplot(5,5,i + 1)
    plt.xticks ( [ ] )
    plt.yticks ( [ ] )
    plt.grid(False)
    plt.imshow(train_images[i],camp=plt.cm.binary)
    plt.xlabel(class_names(train_labels[i]))
plt.show( )
```

Build the model

```
model = keras.Sequential([
    keras.layers.Flatten(input_shape=(28, 28)),
    keras.layers.Dense(128, activation=tf.nn.relu),
    keras.layers.Dense(10, activation=tf.nn.softmax)
])

model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])

model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
flatten_3 (Flatten)          (None, 784)               0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               100480
_________________________________________________________________
dense_5 (Dense)              (None, 10)                1290
=================================================================
Total params: 101,770
Trainable params: 101,770
Non-trainable params: 0
_________________________________________________________________
```

Train and evaluate

```
model.fit(train_images, train_labels, epochs=5)
```

```
Epoch 1/5
60000/60000 [==============================] - 6s 100us/sample - loss: 3.0744 - accuracy: 0.6726
Epoch 2/5
60000/60000 [==============================] - 6s 96us/sample - loss: 0.7389 - accuracy: 0.7142
Epoch 3/5
60000/60000 [==============================] - 5s 83us/sample - loss: 0.6300 - accuracy: 0.7473
Epoch 4/5
60000/60000 [==============================] - 6s 98us/sample - loss: 0.5631 - accuracy: 0.7987
Epoch 5/5
60000/60000 [==============================] - 5s 86us/sample - loss: 0.5366 - accuracy: 0.8128
```

```
test_loss, test_acc = model.evaluate(test_images, test_labels)

print('Test accuracy:', test_acc)
```

```
10000/10000 [==============================] - 1s 63us/sample - loss: 0.6564 - accuracy: 0.7953
Test accuracy: 0.7953
```

Make prediction

```
predictions = model.predict(test_images)
```

```
import numpy as np
np.argmax(predictions[0])
```

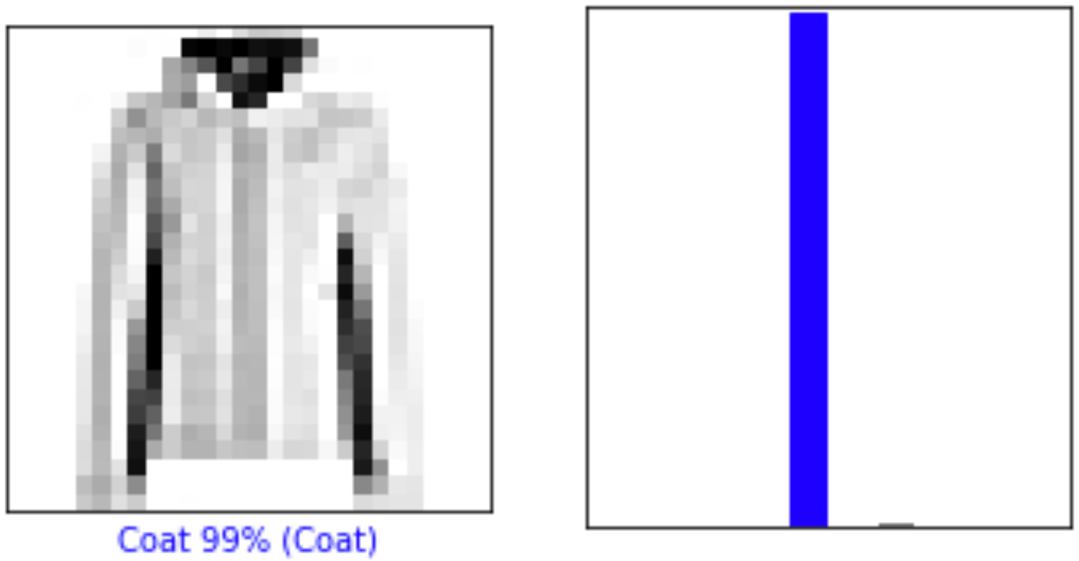
```
9
```

```
test_labels[0]
```

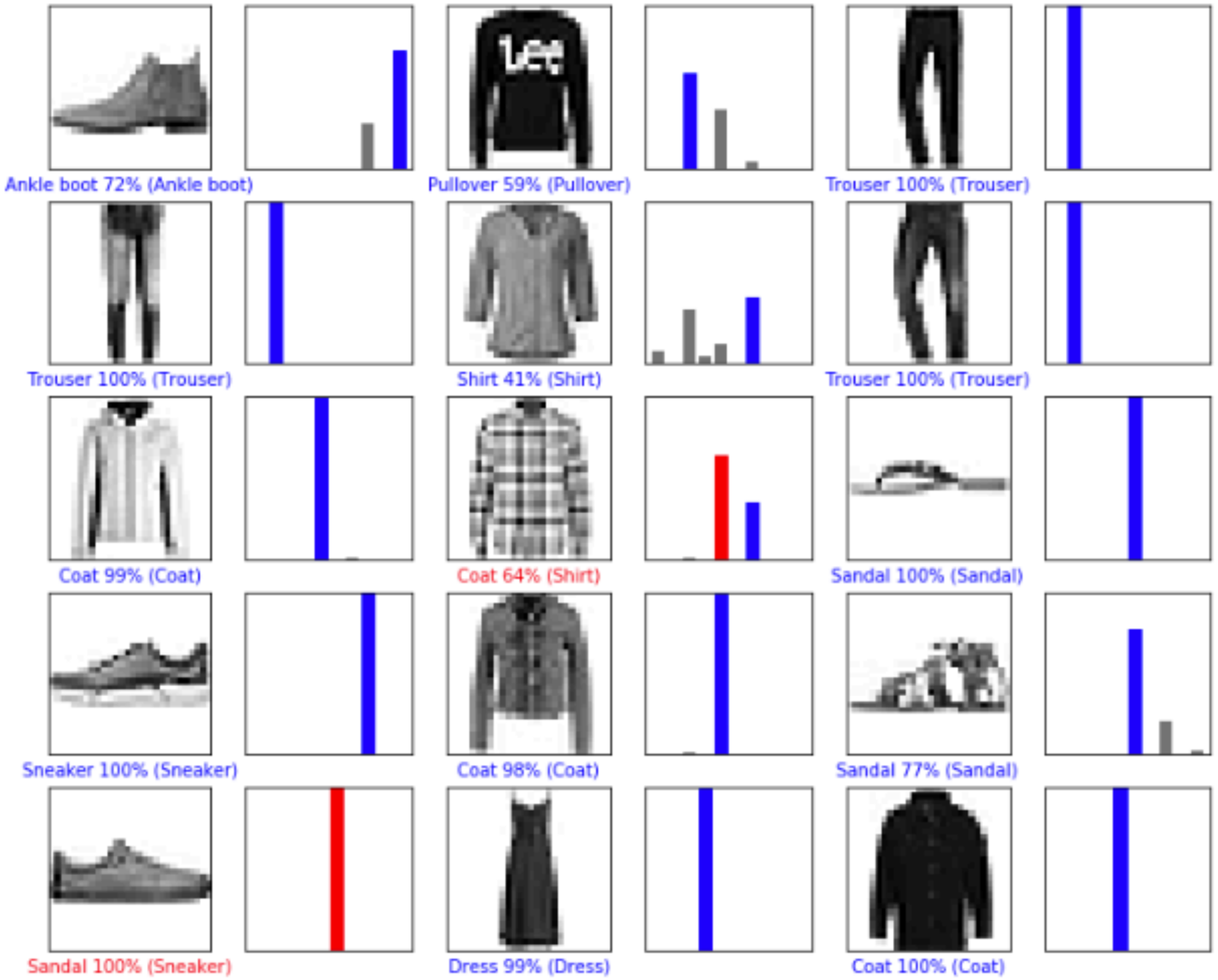
```
9
```

Visualize prediction

```
i = 6
plt.figure(figsize=(6,3))
plt.subplot(1,2,1)
plot_image(i, predictions, test_labels, test_images)
plt.subplot(1,2,2)
plot_value_array(i, predictions, test_labels)
plt.show()
```



Visualize prediction



Try it!

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《TensorFlow 2 项目进阶实战》视频课程