```python
#!/usr/bin/env python

# ECE472-Samuel Maltz
# Assignment 3: Classification of MNIST dataset using convolutional neural netwo
rk

import tensorflow as tf
import numpy as np

from mnist import MNIST
from absl import app
from absl import flags

FLAGS = flags.FLAGS
flags.DEFINE_string("data_dir", "data", "Name of directory with datasets")
flags.DEFINE_list("conv_filters", [3, 2], "Number of filters of convolutional layers")
flags.DEFINE_list("dense_widths", [], "Widths of dense layers")
flags.DEFINE_float("dropout", 0.2, "Dropout rate")
flags.DEFINE_float("learning_rate", 0.001, "Learning rate for Adam optimizer")
flags.DEFINE_integer("epochs", 12, "Number of training epochs")
flags.DEFINE_float("val_split", 0.2, "Validation fraction")
flags.DEFINE_float("kernel_reg", 0.01, "Regularizer coefficient")
flags.DEFINE_integer("random_seed", 12345, "Random seed")


class Data(object):
    def __init__(self, data_dir):
        mndata = MNIST(data_dir)

        self.training_images, self.training_labels = mndata.load_training()
        self.testing_images, self.testing_labels = mndata.load_testing()

        self.training_images = self.preprocess_images(self.training_images)
        self.training_labels = np.array(self.training_labels)
        self.testing_images = self.preprocess_images(self.testing_images)
        self.testing_labels = np.array(self.testing_labels)

    def preprocess_images(self, images):
        return np.reshape(np.array(images), (len(images), 28, 28, 1)).astype("flo
at32")


class Model(tf.keras.Model):
    def __init__(self, conv_filters, dense_widths, dropout, kernel_reg):
        super().__init__()
        self.regularizer = tf.keras.regularizers.L2(kernel_reg)

        self.conv = [
            tf.keras.layers.Conv2D(i, 3, activation="relu") for i in conv_filters
        ]
        self.maxpool = tf.keras.layers.MaxPool2D()
        self.flatten = tf.keras.layers.Flatten()
        self.dense = [
            tf.keras.layers.Dense(
                i, activation="relu", kernel_regularizer=self.regularizer
            )
            for i in dense_widths
        ]
        self.dropout = tf.keras.layers.Dropout(dropout)
        self.final_dense = tf.keras.layers.Dense(
            10, activation="softmax", kernel_regularizer=self.regularizer
        )
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    def call(self, x, training=False):
        for conv_layer in self.conv:
            x = conv_layer(x)
            x = self.maxpool(x)

        x = self.flatten(x)
        for dense_layer in self.dense:
            x = dense_layer(x)
            if training:
                x = self.dropout(x)

        return self.final_dense(x)


def main(a):
    tf.random.set_seed(FLAGS.random_seed)

    data = Data(FLAGS.data_dir)
    model = Model(
        FLAGS.conv_filters, FLAGS.dense_widths, FLAGS.dropout, FLAGS.kernel_reg
    )

    model.compile(
        optimizer=tf.keras.optimizers.Adam(learning_rate=FLAGS.learning_rate),
        loss=tf.keras.losses.SparseCategoricalCrossentropy(),
        metrics=tf.keras.metrics.SparseCategoricalAccuracy(),
    )

    model.fit(
        data.training_images,
        data.training_labels,
        epochs=FLAGS.epochs,
        verbose=2,
        validation_split=FLAGS.val_split,
    )

    model.summary()

    metrics = model.evaluate(data.testing_images, data.testing_labels, verbose=0
)

    print(model.metrics_names[1] + ": " + str(metrics[1]))


if __name__ == "__main__":
    app.run(main)
```

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Epoch 1/12
1500/1500 - 9s - loss: 2.7178 - sparse_categorical_accuracy: 0.3423 - val_loss:
1.1958 - val_sparse_categorical_accuracy: 0.6325
Epoch 2/12
1500/1500 - 8s - loss: 0.7146 - sparse_categorical_accuracy: 0.7986 - val_loss:
0.4039 - val_sparse_categorical_accuracy: 0.8953
Epoch 3/12
1500/1500 - 8s - loss: 0.3286 - sparse_categorical_accuracy: 0.9121 - val_loss:
0.2684 - val_sparse_categorical_accuracy: 0.9297
Epoch 4/12
1500/1500 - 8s - loss: 0.2537 - sparse_categorical_accuracy: 0.9306 - val_loss:
0.2226 - val_sparse_categorical_accuracy: 0.9396
Epoch 5/12
1500/1500 - 8s - loss: 0.2290 - sparse_categorical_accuracy: 0.9375 - val_loss:
0.2155 - val_sparse_categorical_accuracy: 0.9419
Epoch 6/12
1500/1500 - 8s - loss: 0.2158 - sparse_categorical_accuracy: 0.9405 - val_loss:
0.2022 - val_sparse_categorical_accuracy: 0.9477
Epoch 7/12
1500/1500 - 8s - loss: 0.2064 - sparse_categorical_accuracy: 0.9433 - val_loss:
0.1898 - val_sparse_categorical_accuracy: 0.9493
Epoch 8/12
1500/1500 - 8s - loss: 0.1976 - sparse_categorical_accuracy: 0.9459 - val_loss:
0.1903 - val_sparse_categorical_accuracy: 0.9476
Epoch 9/12
1500/1500 - 8s - loss: 0.1948 - sparse_categorical_accuracy: 0.9459 - val_loss:
0.1891 - val_sparse_categorical_accuracy: 0.9496
Epoch 10/12
1500/1500 - 8s - loss: 0.1896 - sparse_categorical_accuracy: 0.9481 - val_loss:
0.1801 - val_sparse_categorical_accuracy: 0.9512
Epoch 11/12
1500/1500 - 8s - loss: 0.1863 - sparse_categorical_accuracy: 0.9480 - val_loss:
0.1787 - val_sparse_categorical_accuracy: 0.9513
Epoch 12/12
1500/1500 - 8s - loss: 0.1867 - sparse_categorical_accuracy: 0.9479 - val_loss:
0.1695 - val_sparse_categorical_accuracy: 0.9545
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              multiple                  30
_________________________________________________________________
conv2d_1 (Conv2D)            multiple                  56
_________________________________________________________________
max_pooling2d (MaxPooling2D) multiple                  0
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flatten (Flatten)            multiple                  0
_________________________________________________________________
dropout (Dropout)            multiple                  0 (unused)
_________________________________________________________________
dense (Dense)                multiple                  510
=================================================================
Total params: 596
Trainable params: 596
Non-trainable params: 0
_________________________________________________________________
sparse_categorical_accuracy: 0.9553999900817871
```