SERVIR's Applied Deep Learning Handbook

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2024-11-14

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1 SERVIR-Applied-Deep-Learning-Book

This is a Quarto website.

To learn more about Quarto websites visit https://servir.github.io/SERVIR-Applied-Deep-Learning-Book/.

Part I

Curriculum

2 Copyright 2024 NASA

```
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```

3 Rice mapping in Bhutan with U-Net using high resolution satellite imagery

Run in Colab

View on GitHub

This notebook is also available in this github repo: https://github.com/SERVIR/servir-aces. Navigate to the `notebooks` folder.

3.1 Setup environment

```
from google.colab import drive
drive.mount("/content/drive")
```

```
Mounted at /content/drive
```

```
!pip install servir-aces
```

```
Collecting servir-aces
  Downloading servir_aces-0.0.14-py2.py3-none-any.whl (32 kB)
Requirement already satisfied: numpy in /usr/local/lib/python3.10/dist-packages (from servir-
Requirement already satisfied: tensorflow>=2.9.3 in /usr/local/lib/python3.10/dist-packages
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  Downloading python_dotenv-1.0.1-py3-none-any.whl (19 kB)
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Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in /usr/local/lib/python3
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Requirement already satisfied: tensorboard<2.16,>=2.15 in /usr/local/lib/python3.10/dist-pack
Requirement already satisfied: tensorflow-estimator<2.16,>=2.15.0 in /usr/local/lib/python3.1
Requirement already satisfied: keras<2.16,>=2.15.0 in /usr/local/lib/python3.10/dist-packages
Requirement already satisfied: google-cloud-storage in /usr/local/lib/python3.10/dist-package
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Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.10/dist-packages
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Requirement already satisfied: google-crc32c<2.0dev,>=1.0 in /usr/local/lib/python3.10/dist-p
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Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.10/dist-packages (f
Installing collected packages: python-dotenv, servir-aces
Successfully installed python-dotenv-1.0.1 servir-aces-0.0.14
```

```
!git clone https://github.com/SERVIR/servir-aces
```

```
Cloning into 'servir-aces'...
remote: Enumerating objects: 740, done.
remote: Counting objects: 100% (116/116), done.
remote: Compressing objects: 100% (78/78), done.
remote: Total 740 (delta 46), reused 68 (delta 38), pack-reused 624
Receiving objects: 100% (740/740), 5.07 MiB | 16.12 MiB/s, done.
Resolving deltas: 100% (468/468), done.
```

3.1.1 Download datasets

For this chapter, we have already prepared and exported the training datasets. They can be found at the google cloud storage and we will use `gsutil` to get the dataset in our workspace. The dataset has `training`, `testing`, and `validation` subdirectory. Let's start by downloading these datasets in our workspace.

If you're looking to produce your own datasets, you can follow this notebook which was used to produce these training, testing, and validation datasets provided in this notebook.

```
!mkdir /content/datasets
```

```
!gsutil -m cp -r gs://dl-book/chapter-1/* /content/datasets
```

```
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==> NOTE: You are downloading one or more large file(s), which would
run significantly faster if you enabled sliced object downloads. This
feature is enabled by default but requires that compiled crcmod be
installed (see "gsutil help crcmod").

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3.1.2 Setup config file variables

Now the repo is downloaded. We will create an environment file file to place point to our training data and customize parameters for the model. To do this, we make a copy of the `.env.example` file provided.

Under the hood, all the configuration provided via the environment file are parsed as a config object and can be accessed programatically.

Note current version does not expose all the model intracacies through the environment file but future version may include those depending on the need.

```
!cp servir-aces/.env.example servir-aces/config.env
```

Okay, now we have the `config.env` file, we will use this to provide our environments and parameters.

Note there are several parameters that can be changed. Let's start by changing the `BASEDIR` and `OUTPUT_DIR` as below.

```
BASEDIR = "/content/"
OUTPUT_DIR = "/content/drive/MyDrive/Colab Notebooks/DL_Book/Chapter_1/output"
```

We will start by training a U-Net model using the `dl-book/chapter-1/unet_256x256_planet_wo_indices` dataset inside the `dataset` folder for this exercise. Let's go ahead and change our DATADIR in the `config.env` file as below.

```
DATADIR = "datasets/unet_256x256_planet_wo_indices"
```

These datasets have RGBN from Planetscope mosiac. Since we are trying to map the rice fields, we use growing season and pre-growing season information. Thus, we have 8 optical bands, namely `red_before`, `green_before`, `blue_before`, `nir_before`, `red_during`, `green_during`, `blue_during`, and `nir_during`. In adidition, you can use `USE_ELEVATION` and `USE_S1` config to include the topographic and radar information. Since this datasets have toppgraphic and radar features, so we won't be settting these config values. Similarly, these datasets are tiled to 256x256 pixels, so let's also change that.

```
# For model training, USE_ELEVATION extends FEATURES with "elevation" & "slope"
# USE_S1 extends FEATURES with "vv_asc_before", "vh_asc_before", "vv_asc_during", "vh_asc_du
# "vv_desc_before", "vh_desc_before", "vv_desc_during", "vh_desc_during"
# In case these are not useful and you have other bands in your training data, you can do se
# USE_ELEVATION and USE_S1 to False and update FEATURES to include needed bands
USE_ELEVATION = False
USE_S1 = False

PATCH_SHAPE = (256, 256)
```

Next, we need to calculate the size of the traiing, testing and validation dataset. For this, we know our size before hand. But `aces` also provides handful of functions that we can use to calculate this. See this notebook to learn more about how to do it. We will also change the `BATCH_SIZE` to 32; if you have larger memory available, you can increase the `BATCH_SIZE`. You can run for longer `EPOCHS` by changing the `EPOCHS` paramter; we will keep it to 5 for now.

```
# Sizes of the training and evaluation datasets.
TRAIN_SIZE = 8531
TEST_SIZE = 1222
VAL_SIZE = 2404
BATCH_SIZE = 32
EPOCHS = 30
```

3.1.3 Update the config file programtically

We can also make a dictionary so we can change these config settings programatically.

```
BASEDIR   = "/content/" # @param {type:"string"}
OUTPUT_DIR = "/content/drive/MyDrive/Colab Notebooks/DL_Book/Chapter_1/output" # @param {type
DATADIR = "datasets/unet_256x256_planet_wo_indices" # @param {type:"string"}
# PATCH_SHAPE, USE_ELEVATION, USE_S1, TRAIN_SIZE, TEST_SIZE, VAL_SIZE
# BATCH_SIZE, EPOCHS are converted to their appropriate type.
USE_ELEVATION = "False" # @param {type:"string"}
USE_S1 = "False" # @param {type:"string"}
PATCH_SHAPE = "(256, 256)" # @param {type:"string"}
TRAIN_SIZE = "8531" # @param {type:"string"}
TEST_SIZE = "1222" # @param {type:"string"}
VAL_SIZE = "2404" # @param {type:"string"}
BATCH_SIZE = "32" # @param {type:"string"}
EPOCHS = "30" # @param {type:"string"}
MODEL_DIR_NAME = "unet_v1" # @param {type:"string"}
```

```
unet_config_settings = {
    "BASEDIR" : BASEDIR,
    "OUTPUT_DIR": OUTPUT_DIR,
    "DATADIR": DATADIR,
    "USE_ELEVATION": USE_ELEVATION,
    "USE_S1": USE_S1,
    "PATCH_SHAPE": PATCH_SHAPE,
    "TRAIN_SIZE": TRAIN_SIZE,
    "TEST_SIZE": TEST_SIZE,
    "VAL_SIZE": VAL_SIZE,
    "BATCH_SIZE": BATCH_SIZE,
    "EPOCHS": EPOCHS,
    "MODEL_DIR_NAME": MODEL_DIR_NAME,
}
```

```
import dotenv

config_file = "servir-aces/config.env"

for config_key in unet_config_settings:
    dotenv.set_key(dotenv_path=config_file,
                   key_to_set=config_key,
                   value_to_set=unet_config_settings[config_key]
                   )
```

3.2 U-Net Model

3.2.1 Load config file variables

```
from aces import Config, DataProcessor, ModelTrainer, EEUtils
```

Let's load our config file through the `Config` class.

```
unet_config = Config(config_file=config_file)
```

```
BASEDIR: /content
DATADIR: /content/datasets/unet_256x256_planet_wo_indices
using features: ['red_before', 'green_before', 'blue_before', 'nir_before', 'red_during', 'gr
using labels: ['class']
```

Most of the config in the `config.env` is now available via the config instance. Let's check few of them here.

```
unet_config.TRAINING_DIR, unet_config.OUTPUT_DIR, unet_config.BATCH_SIZE, unet_config.TRAIN_S
```

```
(PosixPath('/content/datasets/unet_256x256_planet_wo_indices/training'),
 PosixPath('/content/drive/MyDrive/Colab Notebooks/DL_Book/Chapter_1/output'),
 32,
 8531)
```

3.2.2 Load `ModelTrainer` class

Next, let's make an instance of the `ModelTrainer` object. The `ModelTrainer` class provides various tools for training, buidling, compiling, and running specified deep learning models.

```
unet_model_trainer = ModelTrainer(unet_config, seed=42)
```

```
Using seed: 42
```

3.2.3 Train and Save U-Net model

`ModelTrainer` class provides various functionality. We will use `train_model` function that helps to train the model using the provided configuration settings.

This method performs the following steps: - Configures memory growth for TensorFlow. - Creates TensorFlow datasets for training, testing, and validation. - Builds and compiles the model. - Prepares the output directory for saving models and results. - Starts the training process. - Evaluates and prints validation metrics. - Saves training parameters, plots, and models.

```
unet_model_trainer.train_model()
```

```
**********************************************************************
****************************** Clear Session... ******************************
**********************************************************************
****************************** Configure memory growth... ************************
 > Found 1 GPUs
**********************************************************************
****************************** creating datasets... ******************************
Loading dataset from /content/datasets/unet_256x256_planet_wo_indices/training/*
```

```
randomly transforming data
Loading dataset from /content/datasets/unet_256x256_planet_wo_indices/validation/*
Loading dataset from /content/datasets/unet_256x256_planet_wo_indices/testing/*
Printing dataset info:
Training
inputs: float32 (32, 256, 256, 8)
tf.Tensor(
[[[[0.073075 0.063275 0.0411   ... 0.050625 0.0274   0.23925 ]
   [0.084775 0.067375 0.047025 ... 0.057675 0.032075 0.242375]
   [0.083625 0.068575 0.045075 ... 0.059275 0.0332   0.2409  ]
   ...
   [0.0702   0.06825  0.04495  ... 0.055025 0.028325 0.26305 ]
   [0.064475 0.066    0.043575 ... 0.0524   0.027075 0.26705 ]
   [0.0676   0.06355  0.04535  ... 0.05375  0.02875  0.263275]]

  [[0.071475 0.062225 0.0388   ... 0.0496   0.025375 0.24155 ]
   [0.07815  0.065025 0.044225 ... 0.0545   0.02905  0.24175 ]
   [0.086025 0.069125 0.046175 ... 0.05855  0.0326   0.2355  ]
   ...
   [0.060775 0.0627   0.041875 ... 0.051575 0.029725 0.267475]
   [0.061375 0.06225  0.04225  ... 0.0513   0.02685  0.268375]
   [0.06845  0.064075 0.043925 ... 0.052925 0.028575 0.267975]]

  [[0.0677   0.0605   0.038625 ... 0.04835  0.024825 0.236075]
   [0.078375 0.0629   0.04215  ... 0.0524   0.02855  0.237375]
   [0.0857   0.065725 0.04635  ... 0.05705  0.030975 0.235375]
   ...
   [0.07     0.062775 0.04485  ... 0.053425 0.0292   0.27015 ]
   [0.0607   0.060675 0.041175 ... 0.053075 0.026275 0.27025 ]
   [0.068    0.0667   0.045375 ... 0.055475 0.029375 0.262725]]

  ...

  [[0.083525 0.06785  0.044125 ... 0.06365  0.0331   0.234825]
   [0.097825 0.07235  0.047925 ... 0.06675  0.03365  0.2363  ]
   [0.1092   0.082125 0.05385  ... 0.072125 0.036225 0.2486  ]
   ...
   [0.08935  0.088725 0.067575 ... 0.079675 0.042425 0.38085 ]
   [0.093725 0.0875   0.06355  ... 0.07565  0.04185  0.344525]
   [0.0937   0.089675 0.066775 ... 0.07465  0.043025 0.330925]]

  [[0.0893   0.0732   0.04715  ... 0.065    0.0351   0.233525]
   [0.091325 0.073425 0.047475 ... 0.0653   0.032675 0.238325]
```

```
  [0.096775 0.07645  0.051625 ... 0.06875  0.0344   0.252825]
  ...
  [0.0836   0.084875 0.061975 ... 0.07825  0.042875 0.38785 ]
  [0.08865  0.083825 0.060675 ... 0.0765   0.042525 0.3522  ]
  [0.0909   0.084475 0.061975 ... 0.0769   0.043275 0.342625]]

 [[0.092075 0.078    0.050925 ... 0.06565  0.03555  0.235275]
  [0.0805   0.0705   0.043325 ... 0.063925 0.03215  0.243875]
  [0.086925 0.074025 0.0495   ... 0.067475 0.03345  0.26095 ]
  ...
  [0.081075 0.078725 0.056425 ... 0.07505  0.0398   0.37805 ]
  [0.0865   0.079375 0.05845  ... 0.076175 0.0439   0.3619  ]
  [0.0886   0.077775 0.057725 ... 0.076175 0.042825 0.3439  ]]]


[[[0.076525 0.0703   0.04595  ... 0.055225 0.028025 0.25075 ]
  [0.072025 0.0658   0.0446   ... 0.05555  0.02795  0.24755 ]
  [0.0669   0.06225  0.038125 ... 0.05245  0.027125 0.241425]
  ...
  [0.054175 0.050575 0.029475 ... 0.04845  0.022375 0.23045 ]
  [0.05465  0.052375 0.031125 ... 0.04935  0.024375 0.2282  ]
  [0.052525 0.052725 0.029275 ... 0.048325 0.02325  0.229475]]

 [[0.0784   0.065975 0.0441   ... 0.0594   0.031425 0.241175]
  [0.075475 0.066225 0.044975 ... 0.05505  0.02915  0.2405  ]
  [0.073375 0.063225 0.044475 ... 0.05435  0.029375 0.243575]
  ...
  [0.047325 0.05035  0.027125 ... 0.04535  0.022275 0.2235  ]
  [0.046475 0.051075 0.026425 ... 0.047025 0.021025 0.2348  ]
  [0.04295  0.050275 0.02575  ... 0.044525 0.01955  0.240875]]

 [[0.065825 0.0619   0.04045  ... 0.053225 0.026425 0.236775]
  [0.07745  0.062725 0.040725 ... 0.0573   0.030725 0.2439  ]
  [0.075525 0.063775 0.0434   ... 0.05595  0.030125 0.25005 ]
  ...
  [0.046675 0.048325 0.02605  ... 0.0475   0.0219   0.23165 ]
  [0.046825 0.04955  0.026425 ... 0.0471   0.02055  0.243125]
  [0.04435  0.0498   0.0253   ... 0.04675  0.020775 0.239925]]

 ...

 [[0.028025 0.041275 0.01945  ... 0.039375 0.015675 0.22205 ]
  [0.0245   0.040675 0.018025 ... 0.039575 0.016475 0.2187  ]
```

```
  [0.02185  0.03435  0.01665  ... 0.034025 0.015    0.20335 ]
  ...
  [0.1155   0.09395  0.0714   ... 0.058625 0.0275   0.335675]
  [0.117225 0.09435  0.0699   ... 0.05885  0.028175 0.34795 ]
  [0.1168   0.093275 0.06865  ... 0.0585   0.02895  0.353275]]

 [[0.032025 0.04075  0.020675 ... 0.04025  0.015525 0.2328  ]
  [0.024525 0.038175 0.018025 ... 0.03785  0.015075 0.21255 ]
  [0.0227   0.03625  0.016425 ... 0.035    0.015075 0.204675]
  ...
  [0.11625  0.093825 0.071275 ... 0.058625 0.02685  0.34765 ]
  [0.115325 0.092175 0.06915  ... 0.05855  0.02745  0.3572  ]
  [0.1143   0.091225 0.067325 ... 0.05835  0.028925 0.357825]]

 [[0.033325 0.04015  0.0212   ... 0.037875 0.015575 0.220525]
  [0.027225 0.038525 0.01925  ... 0.03625  0.014825 0.207775]
  [0.02625  0.03785  0.01885  ... 0.035675 0.015175 0.209825]
  ...
  [0.1132   0.09225  0.0699   ... 0.057875 0.027175 0.352875]
  [0.1116   0.090575 0.0685   ... 0.0585   0.027325 0.36045 ]
  [0.110325 0.089725 0.06665  ... 0.059425 0.02975  0.35485 ]]]


[[[0.076325 0.0714   0.0511   ... 0.05685  0.027375 0.3285  ]
  [0.078825 0.066725 0.044825 ... 0.05665  0.03155  0.3196  ]
  [0.1038   0.0806   0.060575 ... 0.07545  0.048225 0.2805  ]
  ...
  [0.02885  0.040825 0.022125 ... 0.037725 0.016275 0.17815 ]
  [0.0286   0.0422   0.02355  ... 0.039625 0.016675 0.191225]
  [0.02775  0.04375  0.022175 ... 0.043325 0.0181   0.203775]]

 [[0.06785  0.062075 0.04025  ... 0.04975  0.026175 0.31845 ]
  [0.07785  0.06515  0.041575 ... 0.055275 0.033675 0.29555 ]
  [0.099375 0.0823   0.062    ... 0.076125 0.047775 0.27305 ]
  ...
  [0.026425 0.040625 0.021825 ... 0.037175 0.0163   0.180075]
  [0.0283   0.04245  0.02205  ... 0.04045  0.017175 0.192025]
  [0.02925  0.0436   0.022975 ... 0.043725 0.0179   0.20435 ]]

 [[0.064725 0.0621   0.0413   ... 0.05105  0.02655  0.30515 ]
  [0.08075  0.067625 0.0489   ... 0.0599   0.033625 0.28425 ]
  [0.1018   0.078725 0.060025 ... 0.0735   0.043225 0.2772  ]
  ...
```

```
  [0.0277   0.0412   0.020975 ... 0.03765  0.01625  0.184425]
  [0.02835  0.043125 0.021675 ... 0.040175 0.017375 0.19335 ]
  [0.030575 0.043325 0.023375 ... 0.04225  0.0173   0.200575]]

 ...

 [[0.06545  0.054525 0.034075 ... 0.05745  0.028325 0.244075]
  [0.06275  0.053075 0.03125  ... 0.055625 0.027675 0.247475]
  [0.060875 0.05235  0.030725 ... 0.053875 0.026575 0.247275]
  ...
  [0.04905  0.0508   0.031375 ... 0.039275 0.018625 0.184025]
  [0.047775 0.04855  0.03135  ... 0.038075 0.017725 0.173025]
  [0.048475 0.052025 0.0336   ... 0.0377   0.018625 0.172875]]

 [[0.061575 0.051675 0.03085  ... 0.052975 0.02525  0.244675]
  [0.056875 0.050975 0.027025 ... 0.051675 0.023125 0.243075]
  [0.051075 0.05215  0.027025 ... 0.052125 0.022625 0.2422  ]
  ...
  [0.051525 0.05075  0.031625 ... 0.039625 0.021775 0.1806  ]
  [0.0485   0.049475 0.031275 ... 0.03685  0.01885  0.181675]
  [0.054275 0.054875 0.036125 ... 0.037525 0.0198   0.171425]]

 [[0.055875 0.051075 0.02745  ... 0.04885  0.02285  0.2407  ]
  [0.056    0.052725 0.0285   ... 0.053175 0.02415  0.24375 ]
  [0.0544   0.05275  0.02815  ... 0.0555   0.0232   0.24885 ]
  ...
  [0.05005  0.051775 0.031    ... 0.03915  0.019525 0.1762  ]
  [0.048825 0.051275 0.0324   ... 0.036175 0.018375 0.18395 ]
  [0.0513   0.051225 0.031875 ... 0.0385   0.020625 0.177575]]]


...


[[[0.059125 0.0521   0.0284   ... 0.046025 0.019975 0.234825]
  [0.06905  0.055875 0.0304   ... 0.04825  0.021725 0.237375]
  [0.0699   0.05865  0.031125 ... 0.051375 0.022725 0.23655 ]
  ...
  [0.034575 0.04225  0.0247   ... 0.03785  0.019175 0.157225]
  [0.029975 0.038475 0.023925 ... 0.034475 0.014425 0.175175]
  [0.025325 0.03555  0.02115  ... 0.0325   0.0144   0.157   ]]

 [[0.04895  0.051125 0.02935  ... 0.04475  0.0215   0.2242  ]
```

```
  [0.0563   0.05555  0.032025 ... 0.04655  0.0231   0.224225]
  [0.055875 0.0564   0.032875 ... 0.04815  0.023    0.232925]
  ...
  [0.0347   0.0392   0.0209   ... 0.035425 0.015675 0.17295 ]
  [0.031875 0.0362   0.02055  ... 0.029625 0.013925 0.14845 ]
  [0.028125 0.03385  0.020825 ... 0.026825 0.01315  0.13235 ]]

 [[0.0486   0.0514   0.028275 ... 0.046925 0.022425 0.22335 ]
  [0.05655  0.053425 0.028925 ... 0.047275 0.022825 0.219525]
  [0.0573   0.055525 0.0294   ... 0.0482   0.022275 0.2325  ]
  ...
  [0.024925 0.0378   0.019675 ... 0.032725 0.01405  0.18365 ]
  [0.031925 0.033875 0.0206   ... 0.03015  0.014075 0.169075]
  [0.0316   0.032025 0.019625 ... 0.0268   0.012925 0.136325]]

 ...

 [[0.067175 0.0628   0.039875 ... 0.052775 0.0307   0.2282  ]
  [0.080275 0.071475 0.050425 ... 0.0566   0.0342   0.217525]
  [0.07215  0.068375 0.045875 ... 0.056375 0.034375 0.2167  ]
  ...
  [0.03785  0.041425 0.023875 ... 0.043775 0.019575 0.213625]
  [0.03475  0.0394   0.02255  ... 0.04455  0.02     0.217375]
  [0.032625 0.039025 0.02305  ... 0.043425 0.01985  0.229575]]

 [[0.07875  0.068475 0.0437   ... 0.056175 0.0339   0.22795 ]
  [0.08205  0.073825 0.0498   ... 0.057775 0.035225 0.2253  ]
  [0.08115  0.07405  0.0505   ... 0.059475 0.03475  0.2217  ]
  ...
  [0.03895  0.043275 0.026075 ... 0.044775 0.021    0.2286  ]
  [0.03795  0.038525 0.02265  ... 0.04295  0.018625 0.22255 ]
  [0.03365  0.038425 0.02355  ... 0.042    0.0189   0.225125]]

 [[0.089    0.076325 0.0531   ... 0.05915  0.0333   0.228925]
  [0.084925 0.075775 0.050825 ... 0.05925  0.0363   0.236375]
  [0.08475  0.077325 0.050925 ... 0.0591   0.03615  0.225875]
  ...
  [0.040075 0.0416   0.025975 ... 0.044    0.020425 0.234125]
  [0.038075 0.036475 0.022375 ... 0.042175 0.01925  0.21895 ]
  [0.0349   0.036575 0.0241   ... 0.041525 0.0202   0.223625]]]


[[[0.039875 0.055875 0.031825 ... 0.046725 0.0206   0.2473  ]
```

```
 [0.041225 0.053475 0.031675 ... 0.04425  0.01995  0.2442  ]
 [0.038    0.0509   0.030125 ... 0.04345  0.018975 0.252075]
 ...
 [0.079575 0.068025 0.048175 ... 0.0623   0.0347   0.275575]
 [0.093775 0.08395  0.063975 ... 0.12865  0.096575 0.214425]
 [0.102475 0.09315  0.07065  ... 0.124725 0.11835  0.17915 ]]

[[0.039875 0.055025 0.034025 ... 0.0453   0.020225 0.25715 ]
 [0.039625 0.053725 0.032925 ... 0.0437   0.01945  0.250625]
 [0.03925  0.051775 0.031525 ... 0.0442   0.018825 0.2608  ]
 ...
 [0.080175 0.073025 0.052975 ... 0.06945  0.0391   0.219825]
 [0.09105  0.0811   0.05875  ... 0.09675  0.067    0.133375]
 [0.08775  0.0791   0.053775 ... 0.097075 0.066325 0.1061  ]]

[[0.04015  0.05545  0.0358   ... 0.046    0.020325 0.2604  ]
 [0.0386   0.053425 0.035075 ... 0.04415  0.0186   0.259075]
 [0.038875 0.0541   0.035    ... 0.04585  0.0204   0.2731  ]
 ...
 [0.09545  0.086025 0.06205  ... 0.08275  0.050225 0.117975]
 [0.07805  0.07245  0.05015  ... 0.08905  0.06075  0.088825]
 [0.075975 0.07035  0.04505  ... 0.09075  0.064575 0.082325]]

...

[[0.041475 0.041475 0.021175 ... 0.03885  0.015775 0.209025]
 [0.039625 0.040275 0.021525 ... 0.0381   0.01435  0.199925]
 [0.034975 0.040175 0.020375 ... 0.0356   0.014575 0.1891  ]
 ...
 [0.0552   0.048575 0.034275 ... 0.037725 0.020475 0.150825]
 [0.046975 0.04565  0.03075  ... 0.0352   0.01815  0.137475]
 [0.049075 0.04705  0.031375 ... 0.03935  0.02075  0.1534  ]]

[[0.0475   0.04265  0.024375 ... 0.039125 0.0159   0.2042  ]
 [0.048075 0.042075 0.0262   ... 0.039575 0.015975 0.1975  ]
 [0.0455   0.041725 0.02305  ... 0.0391   0.0166   0.203425]
 ...
 [0.054875 0.04825  0.0329   ... 0.036975 0.020325 0.14335 ]
 [0.04635  0.0461   0.0307   ... 0.0349   0.018575 0.1444  ]
 [0.0477   0.045825 0.030225 ... 0.038175 0.0193   0.14945 ]]

[[0.047625 0.042275 0.025025 ... 0.039375 0.016775 0.2007  ]
 [0.04795  0.043    0.02435  ... 0.039425 0.01655  0.198825]
```

```
  [0.057725 0.04625  0.03155  ... 0.0416   0.0185   0.20395 ]
  ...
  [0.0496   0.04615  0.03035  ... 0.036125 0.01925  0.138325]
  [0.0501   0.047175 0.030225 ... 0.0391   0.0216   0.158675]
  [0.04975  0.048025 0.030475 ... 0.038725 0.021075 0.1527  ]]]


[[[0.09655  0.074775 0.050975 ... 0.0516   0.023025 0.261275]
  [0.092725 0.072675 0.0496   ... 0.058225 0.0292   0.208175]
  [0.080925 0.064725 0.04845  ... 0.08235  0.050425 0.170475]
  ...
  [0.047575 0.051725 0.026375 ... 0.044925 0.017175 0.256825]
  [0.055575 0.052925 0.030125 ... 0.048075 0.018    0.27485 ]
  [0.055525 0.0531   0.0318   ... 0.04635  0.01725  0.256675]]

 [[0.095525 0.07545  0.05235  ... 0.053225 0.022625 0.271925]
  [0.0957   0.075225 0.05265  ... 0.057725 0.02675  0.219325]
  [0.0937   0.071825 0.05245  ... 0.0824   0.05045  0.18085 ]
  ...
  [0.042775 0.048825 0.02565  ... 0.043875 0.016375 0.257325]
  [0.050625 0.051    0.028075 ... 0.04785  0.017925 0.282775]
  [0.0558   0.052    0.029675 ... 0.046875 0.017275 0.268275]]

 [[0.09525  0.076025 0.0528   ... 0.0533   0.021625 0.2891  ]
  [0.09735  0.0765   0.053    ... 0.055425 0.024675 0.244825]
  [0.09475  0.075125 0.05085  ... 0.071575 0.040575 0.1881  ]
  ...
  [0.038275 0.0477   0.0243   ... 0.043325 0.016    0.2494  ]
  [0.04245  0.050225 0.0255   ... 0.046025 0.01685  0.259525]
  [0.0483   0.052175 0.02775  ... 0.04545  0.017225 0.249375]]

 ...

 [[0.033875 0.045775 0.029025 ... 0.0404   0.018975 0.2029  ]
  [0.0357   0.04645  0.028025 ... 0.041925 0.0196   0.20415 ]
  [0.036975 0.046825 0.02825  ... 0.04005  0.018575 0.19235 ]
  ...
  [0.116775 0.0982   0.080175 ... 0.08415  0.06735  0.2857  ]
  [0.104525 0.09055  0.071025 ... 0.0795   0.0627   0.310825]
  [0.0975   0.082025 0.059075 ... 0.06885  0.045825 0.324375]]

 [[0.035775 0.042825 0.02835  ... 0.039125 0.0173   0.20685 ]
  [0.03505  0.0427   0.028275 ... 0.0397   0.017525 0.2041  ]
```

```
   [0.03665  0.0459   0.027125 ... 0.041575 0.0189   0.20055 ]
   ...
   [0.10555  0.088325 0.06645  ... 0.081425 0.059475 0.288725]
   [0.10945  0.091575 0.072325 ... 0.084475 0.057925 0.306175]
   [0.096675 0.0814   0.060425 ... 0.069775 0.04325  0.323975]]

  [[0.0381   0.0465   0.027175 ... 0.0385   0.0179   0.199175]
   [0.036325 0.04335  0.027625 ... 0.037975 0.016925 0.1999  ]
   [0.036475 0.047725 0.029125 ... 0.043325 0.019775 0.21835 ]
   ...
   [0.1108   0.1004   0.0796   ... 0.0981   0.084725 0.291575]
   [0.0959   0.0824   0.06165  ... 0.07685  0.0528   0.318575]
   [0.093025 0.07815  0.0585   ... 0.06915  0.0448   0.32745 ]]]], shape=(32, 256, 256, 8), d
outputs: float32 (32, 256, 256, 5)
tf.Tensor(
[[[[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]]

  ...

  [[1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]
```

```
  [0. 1. 0. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [0. 1. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]]


[[[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
```

```
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]

 ...

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  ...
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]]]


[[[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
```

```
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 ...

 [[0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 1. 0. 0. 0.]
  ...
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]]]


...


[[[0. 0. 1. 0. 0.]
```

```
 [0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 ...
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]]

[[0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 ...
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]]

[[0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 ...
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]]

...

[[0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 ...
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]]

[[0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
 ...
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]
 [1. 0. 0. 0. 0.]]

[[0. 0. 1. 0. 0.]
 [0. 0. 1. 0. 0.]
```

```
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]]


[[[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [0. 0. 0. 1. 0.]
  [0. 0. 0. 1. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [0. 0. 0. 0. 1.]
  [0. 0. 0. 0. 1.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [0. 0. 0. 0. 1.]
  [0. 0. 0. 0. 1.]
  [0. 0. 0. 0. 1.]]

 ...

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
```

```
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]]


[[[0. 0. 1. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 0. 0. 0. 1.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 0. 0. 0. 1.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 [[0. 0. 1. 0. 0.]
  [0. 1. 0. 0. 0.]
  [0. 0. 1. 0. 0.]
  ...
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]
  [1. 0. 0. 0. 0.]]

 ...

 [[0. 0. 1. 0. 0.]
  [0. 0. 1. 0. 0.]
```

```
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 0. 1. 0.]
   [0. 1. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 0. 1. 0.]
   [0. 1. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 0. 0. 1. 0.]
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]]], shape=(32, 256, 256, 5), dtype=float32)
Testing
inputs: float32 (1, 256, 256, 8)
tf.Tensor(
[[[[0.0853   0.0767   0.052625 ... 0.084725 0.048225 0.266675]
   [0.08645  0.076725 0.05415  ... 0.0815   0.049725 0.256475]
   [0.0881   0.07945  0.05675  ... 0.0833   0.049725 0.267   ]
   ...
   [0.041725 0.046875 0.027925 ... 0.04645  0.019175 0.2598  ]
   [0.03835  0.044725 0.024125 ... 0.04525  0.018175 0.2606  ]
   [0.0354   0.03985  0.021875 ... 0.044    0.017925 0.260925]]

  [[0.08945  0.072675 0.047475 ... 0.084925 0.045675 0.253325]
   [0.096    0.07225  0.048375 ... 0.088875 0.049475 0.25065 ]
   [0.10235  0.0735   0.0509   ... 0.088175 0.050675 0.269075]
   ...
   [0.042225 0.0459   0.026575 ... 0.04655  0.01875  0.265025]
   [0.040375 0.044525 0.02595  ... 0.04585  0.0186   0.26045 ]
   [0.03615  0.041075 0.022125 ... 0.044825 0.017775 0.263675]]

  [[0.087625 0.0762   0.0522   ... 0.084775 0.0459   0.243175]
   [0.09235  0.07215  0.048425 ... 0.0871   0.04725  0.243725]
   [0.104925 0.074375 0.05205  ... 0.0889   0.048275 0.25105 ]
```

```
   ...
   [0.04065  0.041975 0.023275 ... 0.043425 0.018075 0.25435 ]
   [0.0382   0.04225  0.02305  ... 0.0432   0.017725 0.254725]
   [0.037025 0.042925 0.022875 ... 0.046575 0.018425 0.259875]]

  ...

  [[0.074575 0.06     0.03945  ... 0.05635  0.03315  0.198025]
   [0.082    0.06205  0.040675 ... 0.058675 0.033075 0.198625]
   [0.080225 0.06355  0.0416   ... 0.059775 0.03395  0.206025]
   ...
   [0.09965  0.082725 0.06805  ... 0.067325 0.05815  0.27725 ]
   [0.0889   0.0679   0.0468   ... 0.0563   0.034875 0.29495 ]
   [0.07205  0.059575 0.04125  ... 0.05235  0.03185  0.3116  ]]

  [[0.0768   0.06205  0.039975 ... 0.058175 0.0334   0.197525]
   [0.0797   0.0638   0.041675 ... 0.060425 0.035925 0.1993  ]
   [0.08345  0.063725 0.04135  ... 0.0606   0.03585  0.2044  ]
   ...
   [0.110425 0.089975 0.071475 ... 0.083225 0.07175  0.261625]
   [0.0995   0.076725 0.053175 ... 0.060975 0.043725 0.29315 ]
   [0.07945  0.06385  0.0462   ... 0.059675 0.038375 0.32095 ]]

  [[0.074075 0.0615   0.0395   ... 0.0591   0.03185  0.200825]
   [0.0771   0.06265  0.040775 ... 0.059825 0.033975 0.204725]
   [0.0835   0.063125 0.0417   ... 0.059825 0.034325 0.2     ]
   ...
   [0.118575 0.0944   0.070325 ... 0.09795  0.078    0.272   ]
   [0.11975  0.0899   0.063575 ... 0.077975 0.05495  0.306325]
   [0.0861   0.068475 0.049775 ... 0.063225 0.039625 0.3163  ]]]], shape=(1, 256, 256, 8), dt
outputs: float32 (1, 256, 256, 5)
tf.Tensor(
[[[[1. 0. 0. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 1. 0. 0. 0.]
   ...
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 0. 1. 0.]
   [0. 0. 0. 1. 0.]
```

```
    ...
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]]

   [[0. 1. 0. 0. 0.]
    [0. 0. 1. 0. 0.]
    [0. 0. 1. 0. 0.]
    ...
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]]

   ...

   [[1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    ...
    [0. 0. 1. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]]

   [[1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    ...
    [0. 0. 0. 1. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]]

   [[1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    [1. 0. 0. 0. 0.]
    ...
    [0. 0. 0. 1. 0.]
    [0. 0. 1. 0. 0.]
    [1. 0. 0. 0. 0.]]]], shape=(1, 256, 256, 5), dtype=float32)
Validation
inputs: float32 (1, 256, 256, 8)
tf.Tensor(
[[[[0.053275 0.043025 0.0284   ... 0.042575 0.01925  0.2313  ]
   [0.0535   0.04265  0.0293   ... 0.043975 0.0191   0.246425]
```

```
 [0.049125 0.042675 0.027125 ... 0.042275 0.019325 0.228225]
 ...
 [0.0724   0.064525 0.044325 ... 0.0504   0.0264   0.202325]
 [0.07395  0.0651   0.04495  ... 0.05235  0.02625  0.211175]
 [0.075975 0.0647   0.04615  ... 0.0523   0.027625 0.2079  ]]

[[0.053025 0.042325 0.02895  ... 0.041625 0.018475 0.239625]
 [0.051225 0.0413   0.029    ... 0.042    0.018375 0.238775]
 [0.04785  0.04345  0.02785  ... 0.042625 0.019825 0.21835 ]
 ...
 [0.067    0.059125 0.042375 ... 0.049375 0.023475 0.18365 ]
 [0.0679   0.06215  0.042125 ... 0.050825 0.0246   0.197125]
 [0.066575 0.062775 0.041925 ... 0.049875 0.0247   0.199775]]

[[0.04975  0.03945  0.0265   ... 0.040925 0.01785  0.243675]
 [0.050625 0.040725 0.027925 ... 0.040825 0.018625 0.236075]
 [0.0546   0.04545  0.029725 ... 0.043575 0.021075 0.20885 ]
 ...
 [0.069075 0.0611   0.0435   ... 0.050075 0.02435  0.186325]
 [0.07345  0.063225 0.0452   ... 0.052325 0.02595  0.19745 ]
 [0.068175 0.06035  0.04155  ... 0.04985  0.023925 0.1912  ]]

...

[[0.064425 0.062275 0.037175 ... 0.0576   0.027975 0.265325]
 [0.058075 0.059925 0.03495  ... 0.05475  0.02585  0.26375 ]
 [0.040675 0.053675 0.028975 ... 0.0482   0.02065  0.250575]
 ...
 [0.0937   0.09025  0.072    ... 0.0486   0.02375  0.2789  ]
 [0.094125 0.091525 0.072925 ... 0.04795  0.02335  0.273275]
 [0.09135  0.08855  0.067875 ... 0.04985  0.023425 0.282475]]

[[0.063175 0.05715  0.03525  ... 0.054475 0.0265   0.2553  ]
 [0.0581   0.0556   0.032875 ... 0.0511   0.0242   0.246625]
 [0.0396   0.0509   0.027975 ... 0.0464   0.020075 0.23445 ]
 ...
 [0.09535  0.0905   0.076275 ... 0.048725 0.0235   0.289175]
 [0.093725 0.09015  0.0717   ... 0.048325 0.02345  0.279575]
 [0.09145  0.088125 0.068475 ... 0.0493   0.023075 0.290275]]

[[0.04605  0.05285  0.0288   ... 0.048925 0.021625 0.2413  ]
 [0.03955  0.051625 0.028325 ... 0.046975 0.020875 0.2319  ]
 [0.0431   0.052225 0.03135  ... 0.042275 0.02     0.221325]
```

```
   ...
   [0.099075 0.085075 0.06545  ... 0.051925 0.02575  0.298475]
   [0.100175 0.08775  0.0678   ... 0.05005  0.024175 0.28905 ]
   [0.09685  0.0912   0.07425  ... 0.049975 0.023375 0.290425]]]], shape=(1, 256, 256, 8), dt
outputs: float32 (1, 256, 256, 5)
tf.Tensor(
[[[[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]
   [1. 0. 0. 0. 0.]]

  ...

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   ...
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
```

```
   ...
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]]

  [[0. 0. 1. 0. 0.]
   [0. 0. 1. 0. 0.]
   [0. 1. 0. 0. 0.]
   ...
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]
   [0. 1. 0. 0. 0.]]]], shape=(1, 256, 256, 5), dtype=float32)
**********************************************************************
********************** building and compiling model... ******************
DERIVE_FEATURES: False
Model: "unet"
_________________________________________________________________________________________________
 Layer (type)                Output Shape                 Param #   Connected to
=================================================================================================
 input_1 (InputLayer)        [(None, None, None, 8)]      0         []

 conv2d (Conv2D)             (None, None, None, 32)       2336      ['input_1[0][0]']

 batch_normalization (Batch  (None, None, None, 32)       128       ['conv2d[0][0]']
 Normalization)

 activation (Activation)     (None, None, None, 32)       0         ['batch_normalization[0]

 activation_1 (Activation)   (None, None, None, 32)       0         ['activation[0][0]']

 separable_conv2d (Separabl  (None, None, None, 64)       2400      ['activation_1[0][0]']
 eConv2D)

 batch_normalization_1 (Bat  (None, None, None, 64)       256       ['separable_conv2d[0][0]
 chNormalization)

 activation_2 (Activation)   (None, None, None, 64)       0         ['batch_normalization_1[0
                                                                    ]

 separable_conv2d_1 (Separa  (None, None, None, 64)       4736      ['activation_2[0][0]']
 bleConv2D)

 batch_normalization_2 (Bat  (None, None, None, 64)       256       ['separable_conv2d_1[0][0
```

```
chNormalization)

max_pooling2d (MaxPooling2  (None, None, None, 64)      0         ['batch_normalization_2[0
D)                                                                ]

conv2d_1 (Conv2D)           (None, None, None, 64)      2112      ['activation[0][0]']

add (Add)                   (None, None, None, 64)      0         ['max_pooling2d[0][0]',
                                                                   'conv2d_1[0][0]']

activation_3 (Activation)   (None, None, None, 64)      0         ['add[0][0]']

separable_conv2d_2 (Separa  (None, None, None, 128)     8896      ['activation_3[0][0]']
bleConv2D)

batch_normalization_3 (Bat  (None, None, None, 128)     512       ['separable_conv2d_2[0][0
chNormalization)

activation_4 (Activation)   (None, None, None, 128)     0         ['batch_normalization_3[0
                                                                  ]

separable_conv2d_3 (Separa  (None, None, None, 128)     17664     ['activation_4[0][0]']
bleConv2D)

batch_normalization_4 (Bat  (None, None, None, 128)     512       ['separable_conv2d_3[0][0
chNormalization)

max_pooling2d_1 (MaxPoolin  (None, None, None, 128)     0         ['batch_normalization_4[0
g2D)                                                              ]

conv2d_2 (Conv2D)           (None, None, None, 128)     8320      ['add[0][0]']

add_1 (Add)                 (None, None, None, 128)     0         ['max_pooling2d_1[0][0]'
                                                                   'conv2d_2[0][0]']

activation_5 (Activation)   (None, None, None, 128)     0         ['add_1[0][0]']

separable_conv2d_4 (Separa  (None, None, None, 256)     34176     ['activation_5[0][0]']
bleConv2D)

batch_normalization_5 (Bat  (None, None, None, 256)     1024      ['separable_conv2d_4[0][0
chNormalization)
```

```
activation_6 (Activation)   (None, None, None, 256)      0         ['batch_normalization_5[0
                                                                    ]']

separable_conv2d_5 (Separa  (None, None, None, 256)      68096     ['activation_6[0][0]']
bleConv2D)

batch_normalization_6 (Bat  (None, None, None, 256)      1024      ['separable_conv2d_5[0][0
chNormalization)                                                    ]']

max_pooling2d_2 (MaxPoolin  (None, None, None, 256)      0         ['batch_normalization_6[0
g2D)                                                                ]']

conv2d_3 (Conv2D)           (None, None, None, 256)      33024     ['add_1[0][0]']

add_2 (Add)                 (None, None, None, 256)      0         ['max_pooling2d_2[0][0]',
                                                                    'conv2d_3[0][0]']

activation_7 (Activation)   (None, None, None, 256)      0         ['add_2[0][0]']

conv2d_transpose (Conv2DTr  (None, None, None, 256)      590080    ['activation_7[0][0]']
anspose)

batch_normalization_7 (Bat  (None, None, None, 256)      1024      ['conv2d_transpose[0][0]
chNormalization)                                                    ']

activation_8 (Activation)   (None, None, None, 256)      0         ['batch_normalization_7[0
                                                                    ]']

conv2d_transpose_1 (Conv2D  (None, None, None, 256)      590080    ['activation_8[0][0]']
Transpose)

batch_normalization_8 (Bat  (None, None, None, 256)      1024      ['conv2d_transpose_1[0][0
chNormalization)                                                    ]']

up_sampling2d_1 (UpSamplin  (None, None, None, 256)      0         ['add_2[0][0]']
g2D)

up_sampling2d (UpSampling2  (None, None, None, 256)      0         ['batch_normalization_8[0
D)                                                                  ]']

conv2d_4 (Conv2D)           (None, None, None, 256)      65792     ['up_sampling2d_1[0][0]']

add_3 (Add)                 (None, None, None, 256)      0         ['up_sampling2d[0][0]',
```

```
                                                                  'conv2d_4[0][0]']

activation_9 (Activation)   (None, None, None, 256)      0         ['add_3[0][0]']

conv2d_transpose_2 (Conv2D  (None, None, None, 128)      295040    ['activation_9[0][0]']
Transpose)

batch_normalization_9 (Bat  (None, None, None, 128)      512       ['conv2d_transpose_2[0][0
chNormalization)

activation_10 (Activation)  (None, None, None, 128)      0         ['batch_normalization_9[0
                                                                  ]']

conv2d_transpose_3 (Conv2D  (None, None, None, 128)      147584    ['activation_10[0][0]']
Transpose)

batch_normalization_10 (Ba  (None, None, None, 128)      512       ['conv2d_transpose_3[0][0
tchNormalization)

up_sampling2d_3 (UpSamplin  (None, None, None, 256)      0         ['add_3[0][0]']
g2D)

up_sampling2d_2 (UpSamplin  (None, None, None, 128)      0         ['batch_normalization_10
g2D)                                                              ']

conv2d_5 (Conv2D)           (None, None, None, 128)      32896     ['up_sampling2d_3[0][0]']

add_4 (Add)                 (None, None, None, 128)      0         ['up_sampling2d_2[0][0]'
                                                                   'conv2d_5[0][0]']

activation_11 (Activation)  (None, None, None, 128)      0         ['add_4[0][0]']

conv2d_transpose_4 (Conv2D  (None, None, None, 64)       73792     ['activation_11[0][0]']
Transpose)

batch_normalization_11 (Ba  (None, None, None, 64)       256       ['conv2d_transpose_4[0][0
tchNormalization)

activation_12 (Activation)  (None, None, None, 64)       0         ['batch_normalization_11
                                                                  ']

conv2d_transpose_5 (Conv2D  (None, None, None, 64)       36928     ['activation_12[0][0]']
Transpose)
```

```
batch_normalization_12 (Ba  (None, None, None, 64)       256       ['conv2d_transpose_5[0][0
tchNormalization)

up_sampling2d_5 (UpSamplin  (None, None, None, 128)      0         ['add_4[0][0]']
g2D)

up_sampling2d_4 (UpSamplin  (None, None, None, 64)       0         ['batch_normalization_12
g2D)                                                               ']

conv2d_6 (Conv2D)           (None, None, None, 64)       8256      ['up_sampling2d_5[0][0]']

add_5 (Add)                 (None, None, None, 64)       0         ['up_sampling2d_4[0][0]'
                                                                    'conv2d_6[0][0]']

activation_13 (Activation)  (None, None, None, 64)       0         ['add_5[0][0]']

conv2d_transpose_6 (Conv2D  (None, None, None, 32)       18464     ['activation_13[0][0]']
Transpose)

batch_normalization_13 (Ba  (None, None, None, 32)       128       ['conv2d_transpose_6[0][0
tchNormalization)

activation_14 (Activation)  (None, None, None, 32)       0         ['batch_normalization_13
                                                                   ']

conv2d_transpose_7 (Conv2D  (None, None, None, 32)       9248      ['activation_14[0][0]']
Transpose)

batch_normalization_14 (Ba  (None, None, None, 32)       128       ['conv2d_transpose_7[0][0
tchNormalization)

up_sampling2d_7 (UpSamplin  (None, None, None, 64)       0         ['add_5[0][0]']
g2D)

up_sampling2d_6 (UpSamplin  (None, None, None, 32)       0         ['batch_normalization_14
g2D)                                                               ']

conv2d_7 (Conv2D)           (None, None, None, 32)       2080      ['up_sampling2d_7[0][0]']

add_6 (Add)                 (None, None, None, 32)       0         ['up_sampling2d_6[0][0]'
                                                                    'conv2d_7[0][0]']
```

```
 final_conv (Conv2D)         (None, None, None, 5)        1445      ['add_6[0][0]']

==================================================================================================
Total params: 2060997 (7.86 MB)
Trainable params: 2057221 (7.85 MB)
Non-trainable params: 3776 (14.75 KB)
__________________________________________________________________________________________________
None
**********************************************************************
********************** preparing output directory... *********************
> Saving models and results at /content/drive/MyDrive/Colab Notebooks/DL_Book/Chapter_1/outpu
**********************************************************************
****************************** training model... ***************************
Epoch 1/30
266/266 [==============================] - ETA: 0s - loss: 0.9676 - precision: 0.7271 - recal
Epoch 1: val_loss improved from inf to 2.63403, saving model to /content/drive/MyDrive/Colab
266/266 [==============================] - 299s 971ms/step - loss: 0.9676 - precision: 0.727
Epoch 2/30
266/266 [==============================] - ETA: 0s - loss: 0.6959 - precision: 0.8066 - recal
Epoch 2: val_loss improved from 2.63403 to 1.23879, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 263s 958ms/step - loss: 0.6959 - precision: 0.8066
Epoch 3/30
266/266 [==============================] - ETA: 0s - loss: 0.6352 - precision: 0.8285 - recal
Epoch 3: val_loss improved from 1.23879 to 0.62282, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 256s 966ms/step - loss: 0.6352 - precision: 0.8285
Epoch 4/30
266/266 [==============================] - ETA: 0s - loss: 0.5988 - precision: 0.8402 - recal
Epoch 4: val_loss improved from 0.62282 to 0.60250, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 252s 949ms/step - loss: 0.5988 - precision: 0.8402
Epoch 5/30
266/266 [==============================] - ETA: 0s - loss: 0.5687 - precision: 0.8498 - recal
Epoch 5: val_loss improved from 0.60250 to 0.55160, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 285s 1s/step - loss: 0.5687 - precision: 0.8498 -
Epoch 6/30
266/266 [==============================] - ETA: 0s - loss: 0.5453 - precision: 0.8571 - recal
Epoch 6: val_loss improved from 0.55160 to 0.52872, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 284s 1s/step - loss: 0.5453 - precision: 0.8571 -
Epoch 7/30
266/266 [==============================] - ETA: 0s - loss: 0.5278 - precision: 0.8624 - recal
Epoch 7: val_loss improved from 0.52872 to 0.50506, saving model to /content/drive/MyDrive/Co
266/266 [==============================] - 262s 988ms/step - loss: 0.5278 - precision: 0.8624
Epoch 8/30
266/266 [==============================] - ETA: 0s - loss: 0.5123 - precision: 0.8671 - recal
```

```
Epoch 8: val_loss improved from 0.50506 to 0.49242, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 264s 995ms/step - loss: 0.5123 - precision: 0.867
Epoch 9/30
266/266 [==============================] - ETA: 0s - loss: 0.5018 - precision: 0.8700 - recal
Epoch 9: val_loss did not improve from 0.49242
266/266 [==============================] - 276s 1s/step - loss: 0.5018 - precision: 0.8700 -
Epoch 10/30
266/266 [==============================] - ETA: 0s - loss: 0.4895 - precision: 0.8736 - recal
Epoch 10: val_loss improved from 0.49242 to 0.47591, saving model to /content/drive/MyDrive/
266/266 [==============================] - 268s 1s/step - loss: 0.4895 - precision: 0.8736 -
Epoch 11/30
266/266 [==============================] - ETA: 0s - loss: 0.4791 - precision: 0.8766 - recal
Epoch 11: val_loss improved from 0.47591 to 0.46856, saving model to /content/drive/MyDrive/
266/266 [==============================] - 263s 992ms/step - loss: 0.4791 - precision: 0.876
Epoch 12/30
266/266 [==============================] - ETA: 0s - loss: 0.4726 - precision: 0.8783 - recal
Epoch 12: val_loss did not improve from 0.46856
266/266 [==============================] - 255s 960ms/step - loss: 0.4726 - precision: 0.878
Epoch 13/30
266/266 [==============================] - ETA: 0s - loss: 0.4617 - precision: 0.8814 - recal
Epoch 13: val_loss improved from 0.46856 to 0.45125, saving model to /content/drive/MyDrive/
266/266 [==============================] - 266s 1s/step - loss: 0.4617 - precision: 0.8814 -
Epoch 14/30
266/266 [==============================] - ETA: 0s - loss: 0.4553 - precision: 0.8830 - recal
Epoch 14: val_loss improved from 0.45125 to 0.44229, saving model to /content/drive/MyDrive/
266/266 [==============================] - 263s 992ms/step - loss: 0.4553 - precision: 0.883
Epoch 15/30
266/266 [==============================] - ETA: 0s - loss: 0.4488 - precision: 0.8847 - recal
Epoch 15: val_loss did not improve from 0.44229
266/266 [==============================] - 258s 973ms/step - loss: 0.4488 - precision: 0.884
Epoch 16/30
266/266 [==============================] - ETA: 0s - loss: 0.4440 - precision: 0.8859 - recal
Epoch 16: val_loss did not improve from 0.44229
266/266 [==============================] - 265s 998ms/step - loss: 0.4440 - precision: 0.885
Epoch 17/30
266/266 [==============================] - ETA: 0s - loss: 0.4378 - precision: 0.8875 - recal
Epoch 17: val_loss did not improve from 0.44229
266/266 [==============================] - 285s 1s/step - loss: 0.4378 - precision: 0.8875 -
Epoch 18/30
266/266 [==============================] - ETA: 0s - loss: 0.4336 - precision: 0.8884 - recal
Epoch 18: val_loss improved from 0.44229 to 0.42199, saving model to /content/drive/MyDrive/
266/266 [==============================] - 278s 1s/step - loss: 0.4336 - precision: 0.8884 -
Epoch 19/30
```

```
266/266 [==============================] - ETA: 0s - loss: 0.4294 - precision: 0.8894 - recal
Epoch 19: val_loss improved from 0.42199 to 0.41151, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 282s 1s/step - loss: 0.4294 - precision: 0.8894 -
Epoch 20/30
266/266 [==============================] - ETA: 0s - loss: 0.4241 - precision: 0.8907 - recal
Epoch 20: val_loss did not improve from 0.41151
266/266 [==============================] - 258s 970ms/step - loss: 0.4241 - precision: 0.890
Epoch 21/30
266/266 [==============================] - ETA: 0s - loss: 0.4196 - precision: 0.8919 - recal
Epoch 21: val_loss did not improve from 0.41151
266/266 [==============================] - 259s 977ms/step - loss: 0.4196 - precision: 0.891
Epoch 22/30
266/266 [==============================] - ETA: 0s - loss: 0.4171 - precision: 0.8923 - recal
Epoch 22: val_loss did not improve from 0.41151
266/266 [==============================] - 260s 982ms/step - loss: 0.4171 - precision: 0.892
Epoch 23/30
266/266 [==============================] - ETA: 0s - loss: 0.4134 - precision: 0.8931 - recal
Epoch 23: val_loss improved from 0.41151 to 0.40218, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 272s 1s/step - loss: 0.4134 - precision: 0.8931 -
Epoch 24/30
266/266 [==============================] - ETA: 0s - loss: 0.4117 - precision: 0.8936 - recal
Epoch 24: val_loss did not improve from 0.40218
266/266 [==============================] - 260s 981ms/step - loss: 0.4117 - precision: 0.893
Epoch 25/30
266/266 [==============================] - ETA: 0s - loss: 0.4064 - precision: 0.8948 - recal
Epoch 25: val_loss improved from 0.40218 to 0.39190, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 298s 1s/step - loss: 0.4064 - precision: 0.8948 -
Epoch 26/30
266/266 [==============================] - ETA: 0s - loss: 0.4038 - precision: 0.8954 - recal
Epoch 26: val_loss improved from 0.39190 to 0.38542, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 280s 1s/step - loss: 0.4038 - precision: 0.8954 -
Epoch 27/30
266/266 [==============================] - ETA: 0s - loss: 0.4007 - precision: 0.8961 - recal
Epoch 27: val_loss improved from 0.38542 to 0.38379, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 283s 1s/step - loss: 0.4007 - precision: 0.8961 -
Epoch 28/30
266/266 [==============================] - ETA: 0s - loss: 0.3972 - precision: 0.8969 - recal
Epoch 28: val_loss improved from 0.38379 to 0.37968, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 264s 996ms/step - loss: 0.3972 - precision: 0.896
Epoch 29/30
266/266 [==============================] - ETA: 0s - loss: 0.3962 - precision: 0.8970 - recal
Epoch 29: val_loss improved from 0.37968 to 0.37328, saving model to /content/drive/MyDrive/C
266/266 [==============================] - 263s 989ms/step - loss: 0.3962 - precision: 0.897
```