Model Training

Importing

In [1]:
```
import tensorflow as tf
from tensorflow.keras.optimizers.schedules import InverseTimeDecay
from model.models import Model_1
from testing import test_model, pred_patches
from dataloader import DataLoader
from model.losses import FocalLoss, WBCE
from model.callbacks import UpdateAccuracy
from ops import reconstruct_image
import os
import json
import shutil
import matplotlib.pyplot as plt
import numpy as np
from tqdm import tqdm
from PIL import Image
from tensorflow.keras.utils import to_categorical
from sklearn.metrics import average_precision_score
```

Parameters

In [2]:
```
# load the params-patches.json options
with open(os.path.join('v1', 'params-patches.json')) as param_file:
    params_patches = json.load(param_file)

# load the params-patches.json options
with open(os.path.join('v1', 'params-training.json')) as param_file:
    params_training = json.load(param_file)

#load the params-model.json options
with open(os.path.join('v1', 'params-model.json')) as param_file:
    params_model = json.load(param_file)

#load the shapes.json options
with open('shapes.json') as param_file:
    shapes_json = json.load(param_file)
```

In [3]:
```
patches_path = params_patches['patches_path']

train_path = os.path.join(patches_path, params_patches['train_sub'])
val_path = os.path.join(patches_path, params_patches['val_sub'])
test_path = os.path.join(patches_path, params_patches['test_sub'])
```

Setting Dataloaders

In [4]:
```
dl_train = DataLoader(
    batch_size = params_training['batch_size'],
    data_path=os.path.join(train_path, params_patches['data_sub']),
    label_path=os.path.join(train_path, params_patches['label_sub']),
    patch_size=128,
    opt_bands=8,
```

```
    sar_bands=4,
    num_classes=3,
    shuffle=True#,
    #limit=params_training['patch_limit']
)

dl_val = DataLoader(
    batch_size=params_training['batch_size'],
    data_path=os.path.join(val_path, params_patches['data_sub']),
    label_path=os.path.join(val_path, params_patches['label_sub']),
    patch_size=128,
    opt_bands=8,
    sar_bands=4,
    num_classes=3#,
    #limit=params_training['patch_limit']
)

dl_test = DataLoader(
    batch_size=params_training['batch_size'],
    data_path=os.path.join(test_path, params_patches['data_sub']),
    label_path=os.path.join(test_path, params_patches['label_sub']),
    patch_size=128,
    opt_bands=8,
    sar_bands=4,
    num_classes=3)
```

Model definition

In [5]:

```
model = Model_1(name='modelo_1')

metrics = {
}

weights = [0.1, 0.9, 0.0]

learning_rate = InverseTimeDecay(
    initial_learning_rate=1e-4,
    decay_steps=params_training['learning_reduction']*len(dl_train),
    decay_rate = 0.01,
    staircase=True
    )

optimizers = {
    'opt': tf.keras.optimizers.Adam(learning_rate = learning_rate),
    'sar': tf.keras.optimizers.Adam(learning_rate = learning_rate),
    'fusion': tf.keras.optimizers.Adam(learning_rate = learning_rate),
}

class_indexes = [0, 1]

model.compile(
    optimizers = optimizers,
    loss_fn = WBCE,
    metrics_dict = metrics,
    class_weights = weights,
    class_indexes = class_indexes,
    run_eagerly=params_training['run_eagerly']
)
```

In [6]:

```
callbacks = [
    tf.keras.callbacks.EarlyStopping(
```

```
        monitor='val_combined_f1score',
        patience = params_training['patience'],
        mode = 'max',
        restore_best_weights=True),
    UpdateAccuracy()
]


history = model.fit(
    x=dl_train,
    validation_data=dl_val,
    epochs=params_training['epochs_train'],
    callbacks=callbacks,
    verbose = 1
    )
```

```
Epoch 1/200
330/330 [==============================] - 267s 806ms/step - opt_loss: 0.2352 - sar_
loss: 0.3304 - fusion_loss: 0.2732 - loss: 0.8389 - opt_accuracy: 0.8680 - sar_accur
acy: 0.8067 - fusion_accuracy: 0.8565 - combined_accuracy: 0.8707 - opt_f1score: 0.7
718 - sar_f1score: 0.6243 - fusion_f1score: 0.7469 - combined_f1score: 0.7737 - val_
opt_loss: 0.3460 - val_sar_loss: 0.9561 - val_fusion_loss: 0.9442 - val_loss: 2.2463
- val_opt_accuracy: 0.6016 - val_sar_accuracy: 0.6016 - val_fusion_accuracy: 0.6016
- val_combined_accuracy: 0.6016 - val_opt_f1score: 4.4280e-14 - val_sar_f1score: 2.0
081e-04 - val_fusion_f1score: 1.5085e-04 - val_combined_f1score: 1.4831e-04
Epoch 2/200
330/330 [==============================] - 119s 361ms/step - opt_loss: 0.1823 - sar_
loss: 0.2596 - fusion_loss: 0.1938 - loss: 0.6356 - opt_accuracy: 0.8889 - sar_accur
acy: 0.8457 - fusion_accuracy: 0.8821 - combined_accuracy: 0.8906 - opt_f1score: 0.8
144 - sar_f1score: 0.7164 - fusion_f1score: 0.8038 - combined_f1score: 0.8150 - val_
opt_loss: 0.1609 - val_sar_loss: 0.3704 - val_fusion_loss: 0.2318 - val_loss: 0.7632
- val_opt_accuracy: 0.8857 - val_sar_accuracy: 0.6086 - val_fusion_accuracy: 0.6903
- val_combined_accuracy: 0.7012 - val_opt_f1score: 0.7283 - val_sar_f1score: 0.0218
- val_fusion_f1score: 0.2401 - val_combined_f1score: 0.2412
Epoch 3/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.1716 - sar_
loss: 0.2465 - fusion_loss: 0.1790 - loss: 0.5971 - opt_accuracy: 0.8936 - sar_accur
acy: 0.8514 - fusion_accuracy: 0.8872 - combined_accuracy: 0.8951 - opt_f1score: 0.8
222 - sar_f1score: 0.7283 - fusion_f1score: 0.8135 - combined_f1score: 0.8231 - val_
opt_loss: 0.1634 - val_sar_loss: 0.2032 - val_fusion_loss: 0.1447 - val_loss: 0.5113
- val_opt_accuracy: 0.8827 - val_sar_accuracy: 0.8391 - val_fusion_accuracy: 0.8712
- val_combined_accuracy: 0.8850 - val_opt_f1score: 0.7636 - val_sar_f1score: 0.5662
- val_fusion_f1score: 0.7401 - val_combined_f1score: 0.7541
Epoch 4/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.1650 - sar_
loss: 0.2366 - fusion_loss: 0.1691 - loss: 0.5707 - opt_accuracy: 0.8963 - sar_accur
acy: 0.8578 - fusion_accuracy: 0.8909 - combined_accuracy: 0.8984 - opt_f1score: 0.8
265 - sar_f1score: 0.7399 - fusion_f1score: 0.8202 - combined_f1score: 0.8291 - val_
opt_loss: 0.2610 - val_sar_loss: 0.2280 - val_fusion_loss: 0.2453 - val_loss: 0.7344
- val_opt_accuracy: 0.6841 - val_sar_accuracy: 0.8422 - val_fusion_accuracy: 0.6991
- val_combined_accuracy: 0.7249 - val_opt_f1score: 0.3384 - val_sar_f1score: 0.5166
- val_fusion_f1score: 0.3713 - val_combined_f1score: 0.3950
Epoch 5/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1576 - sar_
loss: 0.2253 - fusion_loss: 0.1568 - loss: 0.5398 - opt_accuracy: 0.8993 - sar_accur
acy: 0.8599 - fusion_accuracy: 0.8950 - combined_accuracy: 0.9018 - opt_f1score: 0.8
320 - sar_f1score: 0.7487 - fusion_f1score: 0.8304 - combined_f1score: 0.8378 - val_
opt_loss: 0.1293 - val_sar_loss: 0.2009 - val_fusion_loss: 0.1237 - val_loss: 0.4540
- val_opt_accuracy: 0.8976 - val_sar_accuracy: 0.8516 - val_fusion_accuracy: 0.9015
- val_combined_accuracy: 0.9011 - val_opt_f1score: 0.7887 - val_sar_f1score: 0.5980
- val_fusion_f1score: 0.7686 - val_combined_f1score: 0.7721
Epoch 6/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.1501 - sar_
loss: 0.2123 - fusion_loss: 0.1445 - loss: 0.5068 - opt_accuracy: 0.9024 - sar_accur
acy: 0.8646 - fusion_accuracy: 0.8990 - combined_accuracy: 0.9053 - opt_f1score: 0.8
```

```
381 - sar_f1score: 0.7642 - fusion_f1score: 0.8418 - combined_f1score: 0.8483 - val_
opt_loss: 0.1591 - val_sar_loss: 0.2029 - val_fusion_loss: 0.1484 - val_loss: 0.5105
- val_opt_accuracy: 0.8833 - val_sar_accuracy: 0.8013 - val_fusion_accuracy: 0.8948
- val_combined_accuracy: 0.8951 - val_opt_f1score: 0.6890 - val_sar_f1score: 0.5067
- val_fusion_f1score: 0.6841 - val_combined_f1score: 0.6654
Epoch 7/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1435 - sar_
loss: 0.1979 - fusion_loss: 0.1336 - loss: 0.4750 - opt_accuracy: 0.9054 - sar_accur
acy: 0.8699 - fusion_accuracy: 0.9034 - combined_accuracy: 0.9087 - opt_f1score: 0.8
441 - sar_f1score: 0.7799 - fusion_f1score: 0.8521 - combined_f1score: 0.8569 - val_
opt_loss: 0.1356 - val_sar_loss: 0.1981 - val_fusion_loss: 0.1488 - val_loss: 0.4825
- val_opt_accuracy: 0.8898 - val_sar_accuracy: 0.8197 - val_fusion_accuracy: 0.8755
- val_combined_accuracy: 0.8870 - val_opt_f1score: 0.7635 - val_sar_f1score: 0.5462
- val_fusion_f1score: 0.6881 - val_combined_f1score: 0.7183
Epoch 8/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1395 - sar_
loss: 0.1857 - fusion_loss: 0.1253 - loss: 0.4505 - opt_accuracy: 0.9071 - sar_accur
acy: 0.8735 - fusion_accuracy: 0.9067 - combined_accuracy: 0.9113 - opt_f1score: 0.8
479 - sar_f1score: 0.7913 - fusion_f1score: 0.8600 - combined_f1score: 0.8640 - val_
opt_loss: 0.1119 - val_sar_loss: 0.1776 - val_fusion_loss: 0.1089 - val_loss: 0.3983
- val_opt_accuracy: 0.9083 - val_sar_accuracy: 0.8667 - val_fusion_accuracy: 0.9074
- val_combined_accuracy: 0.9053 - val_opt_f1score: 0.8029 - val_sar_f1score: 0.6903
- val_fusion_f1score: 0.8101 - val_combined_f1score: 0.8070
Epoch 9/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1343 - sar_
loss: 0.1781 - fusion_loss: 0.1187 - loss: 0.4311 - opt_accuracy: 0.9088 - sar_accur
acy: 0.8760 - fusion_accuracy: 0.9093 - combined_accuracy: 0.9135 - opt_f1score: 0.8
526 - sar_f1score: 0.7997 - fusion_f1score: 0.8667 - combined_f1score: 0.8703 - val_
opt_loss: 0.1219 - val_sar_loss: 0.2042 - val_fusion_loss: 0.1164 - val_loss: 0.4425
- val_opt_accuracy: 0.9046 - val_sar_accuracy: 0.8364 - val_fusion_accuracy: 0.8981
- val_combined_accuracy: 0.8995 - val_opt_f1score: 0.7774 - val_sar_f1score: 0.6431
- val_fusion_f1score: 0.7880 - val_combined_f1score: 0.7866
Epoch 10/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1305 - sar_
loss: 0.1663 - fusion_loss: 0.1121 - loss: 0.4088 - opt_accuracy: 0.9113 - sar_accur
acy: 0.8803 - fusion_accuracy: 0.9130 - combined_accuracy: 0.9164 - opt_f1score: 0.8
563 - sar_f1score: 0.8112 - fusion_f1score: 0.8730 - combined_f1score: 0.8758 - val_
opt_loss: 0.1351 - val_sar_loss: 0.1536 - val_fusion_loss: 0.1130 - val_loss: 0.4017
- val_opt_accuracy: 0.9000 - val_sar_accuracy: 0.8780 - val_fusion_accuracy: 0.9068
- val_combined_accuracy: 0.9065 - val_opt_f1score: 0.7627 - val_sar_f1score: 0.7167
- val_fusion_f1score: 0.7898 - val_combined_f1score: 0.7960
Epoch 11/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.1239 - sar_
loss: 0.1581 - fusion_loss: 0.1045 - loss: 0.3864 - opt_accuracy: 0.9136 - sar_accur
acy: 0.8840 - fusion_accuracy: 0.9161 - combined_accuracy: 0.9189 - opt_f1score: 0.8
627 - sar_f1score: 0.8206 - fusion_f1score: 0.8808 - combined_f1score: 0.8829 - val_
opt_loss: 0.1192 - val_sar_loss: 0.1655 - val_fusion_loss: 0.1051 - val_loss: 0.3898
- val_opt_accuracy: 0.9050 - val_sar_accuracy: 0.8761 - val_fusion_accuracy: 0.9093
- val_combined_accuracy: 0.9064 - val_opt_f1score: 0.7901 - val_sar_f1score: 0.7073
- val_fusion_f1score: 0.8108 - val_combined_f1score: 0.8069
Epoch 12/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1223 - sar_
loss: 0.1553 - fusion_loss: 0.1018 - loss: 0.3794 - opt_accuracy: 0.9143 - sar_accur
acy: 0.8845 - fusion_accuracy: 0.9177 - combined_accuracy: 0.9200 - opt_f1score: 0.8
644 - sar_f1score: 0.8233 - fusion_f1score: 0.8839 - combined_f1score: 0.8854 - val_
opt_loss: 0.2531 - val_sar_loss: 0.1695 - val_fusion_loss: 0.2220 - val_loss: 0.6446
- val_opt_accuracy: 0.6486 - val_sar_accuracy: 0.8747 - val_fusion_accuracy: 0.6670
- val_combined_accuracy: 0.6870 - val_opt_f1score: 0.3792 - val_sar_f1score: 0.6717
- val_fusion_f1score: 0.4106 - val_combined_f1score: 0.4470
Epoch 13/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1180 - sar_
loss: 0.1465 - fusion_loss: 0.0972 - loss: 0.3617 - opt_accuracy: 0.9163 - sar_accur
acy: 0.8883 - fusion_accuracy: 0.9203 - combined_accuracy: 0.9222 - opt_f1score: 0.8
687 - sar_f1score: 0.8320 - fusion_f1score: 0.8884 - combined_f1score: 0.8898 - val_
opt_loss: 0.1214 - val_sar_loss: 0.1706 - val_fusion_loss: 0.1111 - val_loss: 0.4032
```

```
- val_opt_accuracy: 0.8995 - val_sar_accuracy: 0.8623 - val_fusion_accuracy: 0.9052
- val_combined_accuracy: 0.9068 - val_opt_f1score: 0.7878 - val_sar_f1score: 0.6901
- val_fusion_f1score: 0.8011 - val_combined_f1score: 0.7967
Epoch 14/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1112 - sar_
loss: 0.1382 - fusion_loss: 0.0909 - loss: 0.3404 - opt_accuracy: 0.9189 - sar_accur
acy: 0.8910 - fusion_accuracy: 0.9229 - combined_accuracy: 0.9244 - opt_f1score: 0.8
760 - sar_f1score: 0.8401 - fusion_f1score: 0.8945 - combined_f1score: 0.8954 - val_
opt_loss: 0.1087 - val_sar_loss: 0.1613 - val_fusion_loss: 0.1131 - val_loss: 0.3830
- val_opt_accuracy: 0.9091 - val_sar_accuracy: 0.8783 - val_fusion_accuracy: 0.9063
- val_combined_accuracy: 0.9090 - val_opt_f1score: 0.8094 - val_sar_f1score: 0.7131
- val_fusion_f1score: 0.8050 - val_combined_f1score: 0.8057
Epoch 15/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1111 - sar_
loss: 0.1375 - fusion_loss: 0.0901 - loss: 0.3387 - opt_accuracy: 0.9189 - sar_accur
acy: 0.8906 - fusion_accuracy: 0.9233 - combined_accuracy: 0.9243 - opt_f1score: 0.8
758 - sar_f1score: 0.8404 - fusion_f1score: 0.8956 - combined_f1score: 0.8960 - val_
opt_loss: 0.1087 - val_sar_loss: 0.1673 - val_fusion_loss: 0.0991 - val_loss: 0.3751
- val_opt_accuracy: 0.9056 - val_sar_accuracy: 0.8674 - val_fusion_accuracy: 0.9086
- val_combined_accuracy: 0.9055 - val_opt_f1score: 0.8035 - val_sar_f1score: 0.7338
- val_fusion_f1score: 0.8242 - val_combined_f1score: 0.8183
Epoch 16/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.1046 - sar_
loss: 0.1334 - fusion_loss: 0.0852 - loss: 0.3232 - opt_accuracy: 0.9214 - sar_accur
acy: 0.8925 - fusion_accuracy: 0.9258 - combined_accuracy: 0.9267 - opt_f1score: 0.8
820 - sar_f1score: 0.8449 - fusion_f1score: 0.9005 - combined_f1score: 0.9009 - val_
opt_loss: 0.1078 - val_sar_loss: 0.1850 - val_fusion_loss: 0.1198 - val_loss: 0.4126
- val_opt_accuracy: 0.9108 - val_sar_accuracy: 0.8677 - val_fusion_accuracy: 0.9077
- val_combined_accuracy: 0.9089 - val_opt_f1score: 0.8043 - val_sar_f1score: 0.6472
- val_fusion_f1score: 0.7760 - val_combined_f1score: 0.7688
Epoch 17/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.1028 - sar_
loss: 0.1267 - fusion_loss: 0.0825 - loss: 0.3121 - opt_accuracy: 0.9226 - sar_accur
acy: 0.8955 - fusion_accuracy: 0.9274 - combined_accuracy: 0.9280 - opt_f1score: 0.8
846 - sar_f1score: 0.8521 - fusion_f1score: 0.9035 - combined_f1score: 0.9036 - val_
opt_loss: 0.1074 - val_sar_loss: 0.1489 - val_fusion_loss: 0.0988 - val_loss: 0.3551
- val_opt_accuracy: 0.9149 - val_sar_accuracy: 0.8769 - val_fusion_accuracy: 0.9135
- val_combined_accuracy: 0.9161 - val_opt_f1score: 0.8102 - val_sar_f1score: 0.7466
- val_fusion_f1score: 0.8194 - val_combined_f1score: 0.8244
Epoch 18/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0999 - sar_
loss: 0.1251 - fusion_loss: 0.0800 - loss: 0.3050 - opt_accuracy: 0.9237 - sar_accur
acy: 0.8959 - fusion_accuracy: 0.9288 - combined_accuracy: 0.9292 - opt_f1score: 0.8
876 - sar_f1score: 0.8533 - fusion_f1score: 0.9063 - combined_f1score: 0.9062 - val_
opt_loss: 0.1374 - val_sar_loss: 0.1616 - val_fusion_loss: 0.1067 - val_loss: 0.4058
- val_opt_accuracy: 0.8987 - val_sar_accuracy: 0.8705 - val_fusion_accuracy: 0.9029
- val_combined_accuracy: 0.9072 - val_opt_f1score: 0.7764 - val_sar_f1score: 0.7303
- val_fusion_f1score: 0.8177 - val_combined_f1score: 0.8279
Epoch 19/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0950 - sar_
loss: 0.1180 - fusion_loss: 0.0760 - loss: 0.2890 - opt_accuracy: 0.9264 - sar_accur
acy: 0.8989 - fusion_accuracy: 0.9313 - combined_accuracy: 0.9315 - opt_f1score: 0.8
929 - sar_f1score: 0.8604 - fusion_f1score: 0.9106 - combined_f1score: 0.9103 - val_
opt_loss: 0.1222 - val_sar_loss: 0.1879 - val_fusion_loss: 0.1241 - val_loss: 0.4342
- val_opt_accuracy: 0.8946 - val_sar_accuracy: 0.8672 - val_fusion_accuracy: 0.9013
- val_combined_accuracy: 0.9059 - val_opt_f1score: 0.7825 - val_sar_f1score: 0.7329
- val_fusion_f1score: 0.7921 - val_combined_f1score: 0.7965
Epoch 20/200
330/330 [==============================] - 118s 356ms/step - opt_loss: 0.0941 - sar_
loss: 0.1156 - fusion_loss: 0.0742 - loss: 0.2839 - opt_accuracy: 0.9268 - sar_accur
acy: 0.9004 - fusion_accuracy: 0.9322 - combined_accuracy: 0.9324 - opt_f1score: 0.8
941 - sar_f1score: 0.8637 - fusion_f1score: 0.9127 - combined_f1score: 0.9124 - val_
opt_loss: 0.1075 - val_sar_loss: 0.1523 - val_fusion_loss: 0.0936 - val_loss: 0.3534
- val_opt_accuracy: 0.9141 - val_sar_accuracy: 0.8543 - val_fusion_accuracy: 0.9173
- val_combined_accuracy: 0.9180 - val_opt_f1score: 0.8224 - val_sar_f1score: 0.7250
```

```
- val_fusion_f1score: 0.8377 - val_combined_f1score: 0.8371
Epoch 21/200
330/330 [==============================] - 118s 356ms/step - opt_loss: 0.0895 - sar_
loss: 0.1106 - fusion_loss: 0.0711 - loss: 0.2713 - opt_accuracy: 0.9285 - sar_accur
acy: 0.9024 - fusion_accuracy: 0.9336 - combined_accuracy: 0.9337 - opt_f1score: 0.8
987 - sar_f1score: 0.8689 - fusion_f1score: 0.9157 - combined_f1score: 0.9154 - val_
opt_loss: 0.1042 - val_sar_loss: 0.1692 - val_fusion_loss: 0.1043 - val_loss: 0.3777
- val_opt_accuracy: 0.9118 - val_sar_accuracy: 0.8502 - val_fusion_accuracy: 0.9120
- val_combined_accuracy: 0.9140 - val_opt_f1score: 0.8264 - val_sar_f1score: 0.6921
- val_fusion_f1score: 0.8217 - val_combined_f1score: 0.8208
Epoch 22/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0877 - sar_
loss: 0.1087 - fusion_loss: 0.0699 - loss: 0.2663 - opt_accuracy: 0.9292 - sar_accur
acy: 0.9034 - fusion_accuracy: 0.9343 - combined_accuracy: 0.9342 - opt_f1score: 0.9
005 - sar_f1score: 0.8704 - fusion_f1score: 0.9170 - combined_f1score: 0.9165 - val_
opt_loss: 0.1044 - val_sar_loss: 0.1499 - val_fusion_loss: 0.1001 - val_loss: 0.3544
- val_opt_accuracy: 0.9158 - val_sar_accuracy: 0.8617 - val_fusion_accuracy: 0.9172
- val_combined_accuracy: 0.9186 - val_opt_f1score: 0.8227 - val_sar_f1score: 0.7352
- val_fusion_f1score: 0.8316 - val_combined_f1score: 0.8300
Epoch 23/200
330/330 [==============================] - 120s 363ms/step - opt_loss: 0.0847 - sar_
loss: 0.1059 - fusion_loss: 0.0674 - loss: 0.2579 - opt_accuracy: 0.9312 - sar_accur
acy: 0.9043 - fusion_accuracy: 0.9363 - combined_accuracy: 0.9362 - opt_f1score: 0.9
043 - sar_f1score: 0.8733 - fusion_f1score: 0.9202 - combined_f1score: 0.9197 - val_
opt_loss: 0.1050 - val_sar_loss: 0.1463 - val_fusion_loss: 0.0905 - val_loss: 0.3418
- val_opt_accuracy: 0.9175 - val_sar_accuracy: 0.8852 - val_fusion_accuracy: 0.9180
- val_combined_accuracy: 0.9195 - val_opt_f1score: 0.8339 - val_sar_f1score: 0.7695
- val_fusion_f1score: 0.8484 - val_combined_f1score: 0.8504
Epoch 24/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0862 - sar_
loss: 0.1050 - fusion_loss: 0.0674 - loss: 0.2586 - opt_accuracy: 0.9302 - sar_accur
acy: 0.9042 - fusion_accuracy: 0.9358 - combined_accuracy: 0.9356 - opt_f1score: 0.9
027 - sar_f1score: 0.8738 - fusion_f1score: 0.9200 - combined_f1score: 0.9194 - val_
opt_loss: 0.1007 - val_sar_loss: 0.2074 - val_fusion_loss: 0.1154 - val_loss: 0.4234
- val_opt_accuracy: 0.9163 - val_sar_accuracy: 0.8768 - val_fusion_accuracy: 0.9121
- val_combined_accuracy: 0.9170 - val_opt_f1score: 0.8339 - val_sar_f1score: 0.6981
- val_fusion_f1score: 0.8184 - val_combined_f1score: 0.8183
Epoch 25/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0797 - sar_
loss: 0.1000 - fusion_loss: 0.0635 - loss: 0.2432 - opt_accuracy: 0.9333 - sar_accur
acy: 0.9076 - fusion_accuracy: 0.9387 - combined_accuracy: 0.9383 - opt_f1score: 0.9
094 - sar_f1score: 0.8803 - fusion_f1score: 0.9246 - combined_f1score: 0.9240 - val_
opt_loss: 0.1092 - val_sar_loss: 0.1887 - val_fusion_loss: 0.1165 - val_loss: 0.4143
- val_opt_accuracy: 0.9139 - val_sar_accuracy: 0.8802 - val_fusion_accuracy: 0.9135
- val_combined_accuracy: 0.9157 - val_opt_f1score: 0.8292 - val_sar_f1score: 0.6926
- val_fusion_f1score: 0.8144 - val_combined_f1score: 0.8196
Epoch 26/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0784 - sar_
loss: 0.0944 - fusion_loss: 0.0615 - loss: 0.2342 - opt_accuracy: 0.9341 - sar_accur
acy: 0.9106 - fusion_accuracy: 0.9399 - combined_accuracy: 0.9395 - opt_f1score: 0.9
109 - sar_f1score: 0.8860 - fusion_f1score: 0.9267 - combined_f1score: 0.9262 - val_
opt_loss: 0.1347 - val_sar_loss: 0.1795 - val_fusion_loss: 0.1069 - val_loss: 0.4212
- val_opt_accuracy: 0.9080 - val_sar_accuracy: 0.8817 - val_fusion_accuracy: 0.9130
- val_combined_accuracy: 0.9168 - val_opt_f1score: 0.7878 - val_sar_f1score: 0.7224
- val_fusion_f1score: 0.8318 - val_combined_f1score: 0.8337
Epoch 27/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0774 - sar_
loss: 0.1049 - fusion_loss: 0.0625 - loss: 0.2448 - opt_accuracy: 0.9345 - sar_accur
acy: 0.9066 - fusion_accuracy: 0.9396 - combined_accuracy: 0.9393 - opt_f1score: 0.9
121 - sar_f1score: 0.8757 - fusion_f1score: 0.9259 - combined_f1score: 0.9255 - val_
opt_loss: 0.1041 - val_sar_loss: 0.1588 - val_fusion_loss: 0.0963 - val_loss: 0.3592
- val_opt_accuracy: 0.9199 - val_sar_accuracy: 0.8889 - val_fusion_accuracy: 0.9216
- val_combined_accuracy: 0.9203 - val_opt_f1score: 0.8409 - val_sar_f1score: 0.7709
- val_fusion_f1score: 0.8452 - val_combined_f1score: 0.8441
Epoch 28/200
```

```
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0766 - sar_
loss: 0.0946 - fusion_loss: 0.0606 - loss: 0.2318 - opt_accuracy: 0.9352 - sar_accur
acy: 0.9115 - fusion_accuracy: 0.9410 - combined_accuracy: 0.9404 - opt_f1score: 0.9
132 - sar_f1score: 0.8865 - fusion_f1score: 0.9280 - combined_f1score: 0.9274 - val_
opt_loss: 0.1088 - val_sar_loss: 0.1766 - val_fusion_loss: 0.1084 - val_loss: 0.3938
- val_opt_accuracy: 0.9129 - val_sar_accuracy: 0.8866 - val_fusion_accuracy: 0.9150
- val_combined_accuracy: 0.9151 - val_opt_f1score: 0.8329 - val_sar_f1score: 0.7248
- val_fusion_f1score: 0.8343 - val_combined_f1score: 0.8321
Epoch 29/200
330/330 [==============================] - 118s 356ms/step - opt_loss: 0.0729 - sar_
loss: 0.0896 - fusion_loss: 0.0577 - loss: 0.2202 - opt_accuracy: 0.9369 - sar_accur
acy: 0.9138 - fusion_accuracy: 0.9428 - combined_accuracy: 0.9423 - opt_f1score: 0.9
170 - sar_f1score: 0.8919 - fusion_f1score: 0.9313 - combined_f1score: 0.9308 - val_
opt_loss: 0.1055 - val_sar_loss: 0.2503 - val_fusion_loss: 0.1350 - val_loss: 0.4907
- val_opt_accuracy: 0.9156 - val_sar_accuracy: 0.8594 - val_fusion_accuracy: 0.9044
- val_combined_accuracy: 0.9017 - val_opt_f1score: 0.8462 - val_sar_f1score: 0.7459
- val_fusion_f1score: 0.8344 - val_combined_f1score: 0.8315
Epoch 30/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0754 - sar_
loss: 0.0885 - fusion_loss: 0.0579 - loss: 0.2217 - opt_accuracy: 0.9361 - sar_accur
acy: 0.9148 - fusion_accuracy: 0.9429 - combined_accuracy: 0.9424 - opt_f1score: 0.9
144 - sar_f1score: 0.8930 - fusion_f1score: 0.9312 - combined_f1score: 0.9307 - val_
opt_loss: 0.1024 - val_sar_loss: 0.1597 - val_fusion_loss: 0.0936 - val_loss: 0.3556
- val_opt_accuracy: 0.9241 - val_sar_accuracy: 0.8827 - val_fusion_accuracy: 0.9239
- val_combined_accuracy: 0.9258 - val_opt_f1score: 0.8563 - val_sar_f1score: 0.7516
- val_fusion_f1score: 0.8534 - val_combined_f1score: 0.8540
Epoch 31/200
330/330 [==============================] - 119s 359ms/step - opt_loss: 0.0727 - sar_
loss: 0.0891 - fusion_loss: 0.0570 - loss: 0.2187 - opt_accuracy: 0.9370 - sar_accur
acy: 0.9143 - fusion_accuracy: 0.9433 - combined_accuracy: 0.9427 - opt_f1score: 0.9
175 - sar_f1score: 0.8928 - fusion_f1score: 0.9322 - combined_f1score: 0.9316 - val_
opt_loss: 0.1144 - val_sar_loss: 0.1673 - val_fusion_loss: 0.1054 - val_loss: 0.3871
- val_opt_accuracy: 0.9058 - val_sar_accuracy: 0.8893 - val_fusion_accuracy: 0.9118
- val_combined_accuracy: 0.9157 - val_opt_f1score: 0.8229 - val_sar_f1score: 0.7591
- val_fusion_f1score: 0.8386 - val_combined_f1score: 0.8399
Epoch 32/200
330/330 [==============================] - 118s 359ms/step - opt_loss: 0.0702 - sar_
loss: 0.0857 - fusion_loss: 0.0553 - loss: 0.2111 - opt_accuracy: 0.9386 - sar_accur
acy: 0.9167 - fusion_accuracy: 0.9448 - combined_accuracy: 0.9442 - opt_f1score: 0.9
202 - sar_f1score: 0.8963 - fusion_f1score: 0.9342 - combined_f1score: 0.9337 - val_
opt_loss: 0.1103 - val_sar_loss: 0.2645 - val_fusion_loss: 0.1507 - val_loss: 0.5256
- val_opt_accuracy: 0.9141 - val_sar_accuracy: 0.8632 - val_fusion_accuracy: 0.9012
- val_combined_accuracy: 0.9007 - val_opt_f1score: 0.8151 - val_sar_f1score: 0.6781
- val_fusion_f1score: 0.7855 - val_combined_f1score: 0.7792
Epoch 33/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0682 - sar_
loss: 0.0825 - fusion_loss: 0.0535 - loss: 0.2041 - opt_accuracy: 0.9397 - sar_accur
acy: 0.9183 - fusion_accuracy: 0.9462 - combined_accuracy: 0.9456 - opt_f1score: 0.9
224 - sar_f1score: 0.8998 - fusion_f1score: 0.9364 - combined_f1score: 0.9359 - val_
opt_loss: 0.1081 - val_sar_loss: 0.1464 - val_fusion_loss: 0.0937 - val_loss: 0.3482
- val_opt_accuracy: 0.9208 - val_sar_accuracy: 0.8871 - val_fusion_accuracy: 0.9229
- val_combined_accuracy: 0.9222 - val_opt_f1score: 0.8513 - val_sar_f1score: 0.7814
- val_fusion_f1score: 0.8585 - val_combined_f1score: 0.8576
Epoch 34/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0671 - sar_
loss: 0.0812 - fusion_loss: 0.0525 - loss: 0.2007 - opt_accuracy: 0.9404 - sar_accur
acy: 0.9195 - fusion_accuracy: 0.9470 - combined_accuracy: 0.9463 - opt_f1score: 0.9
238 - sar_f1score: 0.9015 - fusion_f1score: 0.9376 - combined_f1score: 0.9371 - val_
opt_loss: 0.1098 - val_sar_loss: 0.1932 - val_fusion_loss: 0.0969 - val_loss: 0.3999
- val_opt_accuracy: 0.9211 - val_sar_accuracy: 0.8916 - val_fusion_accuracy: 0.9242
- val_combined_accuracy: 0.9242 - val_opt_f1score: 0.8542 - val_sar_f1score: 0.7301
- val_fusion_f1score: 0.8606 - val_combined_f1score: 0.8614
Epoch 35/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0661 - sar_
loss: 0.0793 - fusion_loss: 0.0516 - loss: 0.1970 - opt_accuracy: 0.9406 - sar_accur
```

```
acy: 0.9208 - fusion_accuracy: 0.9475 - combined_accuracy: 0.9469 - opt_f1score: 0.9
246 - sar_f1score: 0.9037 - fusion_f1score: 0.9385 - combined_f1score: 0.9381 - val_
opt_loss: 0.1140 - val_sar_loss: 0.2050 - val_fusion_loss: 0.1219 - val_loss: 0.4409
- val_opt_accuracy: 0.9144 - val_sar_accuracy: 0.8874 - val_fusion_accuracy: 0.9175
- val_combined_accuracy: 0.9194 - val_opt_f1score: 0.8277 - val_sar_f1score: 0.7603
- val_fusion_f1score: 0.8274 - val_combined_f1score: 0.8303
Epoch 36/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0655 - sar_
loss: 0.0784 - fusion_loss: 0.0511 - loss: 0.1950 - opt_accuracy: 0.9415 - sar_accur
acy: 0.9218 - fusion_accuracy: 0.9485 - combined_accuracy: 0.9478 - opt_f1score: 0.9
256 - sar_f1score: 0.9048 - fusion_f1score: 0.9395 - combined_f1score: 0.9390 - val_
opt_loss: 0.1073 - val_sar_loss: 0.2818 - val_fusion_loss: 0.1479 - val_loss: 0.5369
- val_opt_accuracy: 0.9191 - val_sar_accuracy: 0.8776 - val_fusion_accuracy: 0.9125
- val_combined_accuracy: 0.9182 - val_opt_f1score: 0.8387 - val_sar_f1score: 0.6560
- val_fusion_f1score: 0.8078 - val_combined_f1score: 0.8122
Epoch 37/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0650 - sar_
loss: 0.0804 - fusion_loss: 0.0512 - loss: 0.1966 - opt_accuracy: 0.9419 - sar_accur
acy: 0.9214 - fusion_accuracy: 0.9487 - combined_accuracy: 0.9481 - opt_f1score: 0.9
263 - sar_f1score: 0.9035 - fusion_f1score: 0.9396 - combined_f1score: 0.9391 - val_
opt_loss: 0.1010 - val_sar_loss: 0.2243 - val_fusion_loss: 0.1115 - val_loss: 0.4367
- val_opt_accuracy: 0.9246 - val_sar_accuracy: 0.8888 - val_fusion_accuracy: 0.9260
- val_combined_accuracy: 0.9245 - val_opt_f1score: 0.8498 - val_sar_f1score: 0.7414
- val_fusion_f1score: 0.8458 - val_combined_f1score: 0.8440
Epoch 38/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0673 - sar_
loss: 0.0761 - fusion_loss: 0.0507 - loss: 0.1941 - opt_accuracy: 0.9412 - sar_accur
acy: 0.9239 - fusion_accuracy: 0.9489 - combined_accuracy: 0.9484 - opt_f1score: 0.9
241 - sar_f1score: 0.9081 - fusion_f1score: 0.9400 - combined_f1score: 0.9397 - val_
opt_loss: 0.1086 - val_sar_loss: 0.2005 - val_fusion_loss: 0.1097 - val_loss: 0.4188
- val_opt_accuracy: 0.9155 - val_sar_accuracy: 0.8757 - val_fusion_accuracy: 0.9144
- val_combined_accuracy: 0.9128 - val_opt_f1score: 0.8442 - val_sar_f1score: 0.7766
- val_fusion_f1score: 0.8458 - val_combined_f1score: 0.8459
Epoch 39/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0632 - sar_
loss: 0.0757 - fusion_loss: 0.0495 - loss: 0.1884 - opt_accuracy: 0.9429 - sar_accur
acy: 0.9242 - fusion_accuracy: 0.9500 - combined_accuracy: 0.9494 - opt_f1score: 0.9
282 - sar_f1score: 0.9086 - fusion_f1score: 0.9415 - combined_f1score: 0.9412 - val_
opt_loss: 0.1100 - val_sar_loss: 0.2324 - val_fusion_loss: 0.1248 - val_loss: 0.4672
- val_opt_accuracy: 0.9189 - val_sar_accuracy: 0.8779 - val_fusion_accuracy: 0.9128
- val_combined_accuracy: 0.9197 - val_opt_f1score: 0.8450 - val_sar_f1score: 0.6954
- val_fusion_f1score: 0.8261 - val_combined_f1score: 0.8329
Epoch 40/200
330/330 [==============================] - 118s 357ms/step - opt_loss: 0.0610 - sar_
loss: 0.0725 - fusion_loss: 0.0476 - loss: 0.1811 - opt_accuracy: 0.9444 - sar_accur
acy: 0.9266 - fusion_accuracy: 0.9516 - combined_accuracy: 0.9510 - opt_f1score: 0.9
308 - sar_f1score: 0.9122 - fusion_f1score: 0.9437 - combined_f1score: 0.9434 - val_
opt_loss: 0.1098 - val_sar_loss: 0.1702 - val_fusion_loss: 0.1054 - val_loss: 0.3855
- val_opt_accuracy: 0.9187 - val_sar_accuracy: 0.8994 - val_fusion_accuracy: 0.9211
- val_combined_accuracy: 0.9242 - val_opt_f1score: 0.8434 - val_sar_f1score: 0.7828
- val_fusion_f1score: 0.8494 - val_combined_f1score: 0.8490
Epoch 41/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.0602 - sar_
loss: 0.0700 - fusion_loss: 0.0467 - loss: 0.1769 - opt_accuracy: 0.9454 - sar_accur
acy: 0.9285 - fusion_accuracy: 0.9530 - combined_accuracy: 0.9524 - opt_f1score: 0.9
318 - sar_f1score: 0.9152 - fusion_f1score: 0.9453 - combined_f1score: 0.9450 - val_
opt_loss: 0.1185 - val_sar_loss: 0.2078 - val_fusion_loss: 0.1199 - val_loss: 0.4462
- val_opt_accuracy: 0.9137 - val_sar_accuracy: 0.8465 - val_fusion_accuracy: 0.9145
- val_combined_accuracy: 0.9180 - val_opt_f1score: 0.8391 - val_sar_f1score: 0.6947
- val_fusion_f1score: 0.8332 - val_combined_f1score: 0.8352
Epoch 42/200
330/330 [==============================] - 120s 364ms/step - opt_loss: 0.0589 - sar_
loss: 0.0704 - fusion_loss: 0.0461 - loss: 0.1754 - opt_accuracy: 0.9459 - sar_accur
acy: 0.9285 - fusion_accuracy: 0.9533 - combined_accuracy: 0.9528 - opt_f1score: 0.9
331 - sar_f1score: 0.9148 - fusion_f1score: 0.9458 - combined_f1score: 0.9455 - val_
```

```
opt_loss: 0.1074 - val_sar_loss: 0.3211 - val_fusion_loss: 0.1570 - val_loss: 0.5856
- val_opt_accuracy: 0.9187 - val_sar_accuracy: 0.8235 - val_fusion_accuracy: 0.9008
- val_combined_accuracy: 0.9001 - val_opt_f1score: 0.8472 - val_sar_f1score: 0.7368
- val_fusion_f1score: 0.8378 - val_combined_f1score: 0.8369
Epoch 43/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0602 - sar_
loss: 0.0709 - fusion_loss: 0.0465 - loss: 0.1776 - opt_accuracy: 0.9452 - sar_accur
acy: 0.9281 - fusion_accuracy: 0.9530 - combined_accuracy: 0.9525 - opt_f1score: 0.9
318 - sar_f1score: 0.9144 - fusion_f1score: 0.9454 - combined_f1score: 0.9452 - val_
opt_loss: 0.1047 - val_sar_loss: 0.1919 - val_fusion_loss: 0.1052 - val_loss: 0.4019
- val_opt_accuracy: 0.9283 - val_sar_accuracy: 0.8902 - val_fusion_accuracy: 0.9270
- val_combined_accuracy: 0.9249 - val_opt_f1score: 0.8634 - val_sar_f1score: 0.7890
- val_fusion_f1score: 0.8622 - val_combined_f1score: 0.8601
Epoch 44/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0577 - sar_
loss: 0.0676 - fusion_loss: 0.0448 - loss: 0.1701 - opt_accuracy: 0.9468 - sar_accur
acy: 0.9309 - fusion_accuracy: 0.9546 - combined_accuracy: 0.9542 - opt_f1score: 0.9
344 - sar_f1score: 0.9184 - fusion_f1score: 0.9476 - combined_f1score: 0.9473 - val_
opt_loss: 0.0994 - val_sar_loss: 0.2604 - val_fusion_loss: 0.1214 - val_loss: 0.4812
- val_opt_accuracy: 0.9245 - val_sar_accuracy: 0.8668 - val_fusion_accuracy: 0.9178
- val_combined_accuracy: 0.9138 - val_opt_f1score: 0.8509 - val_sar_f1score: 0.7284
- val_fusion_f1score: 0.8424 - val_combined_f1score: 0.8362
Epoch 45/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0592 - sar_
loss: 0.0711 - fusion_loss: 0.0460 - loss: 0.1763 - opt_accuracy: 0.9466 - sar_accur
acy: 0.9286 - fusion_accuracy: 0.9541 - combined_accuracy: 0.9536 - opt_f1score: 0.9
334 - sar_f1score: 0.9146 - fusion_f1score: 0.9464 - combined_f1score: 0.9461 - val_
opt_loss: 0.1201 - val_sar_loss: 0.3071 - val_fusion_loss: 0.1654 - val_loss: 0.5926
- val_opt_accuracy: 0.9197 - val_sar_accuracy: 0.8711 - val_fusion_accuracy: 0.9157
- val_combined_accuracy: 0.9147 - val_opt_f1score: 0.8292 - val_sar_f1score: 0.6893
- val_fusion_f1score: 0.8116 - val_combined_f1score: 0.8080
Epoch 46/200
330/330 [==============================] - 119s 360ms/step - opt_loss: 0.0571 - sar_
loss: 0.0673 - fusion_loss: 0.0444 - loss: 0.1687 - opt_accuracy: 0.9476 - sar_accur
acy: 0.9312 - fusion_accuracy: 0.9551 - combined_accuracy: 0.9547 - opt_f1score: 0.9
355 - sar_f1score: 0.9188 - fusion_f1score: 0.9482 - combined_f1score: 0.9480 - val_
opt_loss: 0.1025 - val_sar_loss: 0.1793 - val_fusion_loss: 0.0960 - val_loss: 0.3779
- val_opt_accuracy: 0.9211 - val_sar_accuracy: 0.7609 - val_fusion_accuracy: 0.9144
- val_combined_accuracy: 0.9150 - val_opt_f1score: 0.8477 - val_sar_f1score: 0.6348
- val_fusion_f1score: 0.8465 - val_combined_f1score: 0.8455
Epoch 47/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.0576 - sar_
loss: 0.0678 - fusion_loss: 0.0446 - loss: 0.1700 - opt_accuracy: 0.9475 - sar_accur
acy: 0.9310 - fusion_accuracy: 0.9553 - combined_accuracy: 0.9549 - opt_f1score: 0.9
350 - sar_f1score: 0.9183 - fusion_f1score: 0.9482 - combined_f1score: 0.9480 - val_
opt_loss: 0.1065 - val_sar_loss: 0.1677 - val_fusion_loss: 0.1052 - val_loss: 0.3794
- val_opt_accuracy: 0.9214 - val_sar_accuracy: 0.8676 - val_fusion_accuracy: 0.9118
- val_combined_accuracy: 0.9157 - val_opt_f1score: 0.8541 - val_sar_f1score: 0.7499
- val_fusion_f1score: 0.8453 - val_combined_f1score: 0.8484
Epoch 48/200
330/330 [==============================] - 118s 358ms/step - opt_loss: 0.0551 - sar_
loss: 0.0653 - fusion_loss: 0.0431 - loss: 0.1635 - opt_accuracy: 0.9488 - sar_accur
acy: 0.9329 - fusion_accuracy: 0.9563 - combined_accuracy: 0.9559 - opt_f1score: 0.9
376 - sar_f1score: 0.9214 - fusion_f1score: 0.9498 - combined_f1score: 0.9496 - val_
opt_loss: 0.1061 - val_sar_loss: 0.1941 - val_fusion_loss: 0.1066 - val_loss: 0.4068
- val_opt_accuracy: 0.9198 - val_sar_accuracy: 0.8832 - val_fusion_accuracy: 0.9227
- val_combined_accuracy: 0.9220 - val_opt_f1score: 0.8575 - val_sar_f1score: 0.7870
- val_fusion_f1score: 0.8599 - val_combined_f1score: 0.8593
Epoch 49/200
330/330 [==============================] - 119s 362ms/step - opt_loss: 0.0545 - sar_
loss: 0.0628 - fusion_loss: 0.0420 - loss: 0.1593 - opt_accuracy: 0.9492 - sar_accur
acy: 0.9350 - fusion_accuracy: 0.9574 - combined_accuracy: 0.9570 - opt_f1score: 0.9
382 - sar_f1score: 0.9242 - fusion_f1score: 0.9511 - combined_f1score: 0.9509 - val_
opt_loss: 0.1082 - val_sar_loss: 0.2250 - val_fusion_loss: 0.1197 - val_loss: 0.4529
- val_opt_accuracy: 0.9242 - val_sar_accuracy: 0.8936 - val_fusion_accuracy: 0.9242
```

```
- val_combined_accuracy: 0.9272 - val_opt_f1score: 0.8625 - val_sar_f1score: 0.7205
- val_fusion_f1score: 0.8486 - val_combined_f1score: 0.8523
```

Show training history

In [7]:

```
plt.figure(figsize=(15, 8))
x = np.arange(len(history.history['loss']))+1
plt.plot(x, history.history['loss'], 'r-',label='Total Loss')
plt.plot(x, history.history['opt_loss'], 'r:',label='OPT Loss')
plt.plot(x, history.history['sar_loss'], 'r--',label='SAR Loss')
plt.plot(x, history.history['fusion_loss'], 'r-.',label='FUSION Loss')

plt.plot(x, history.history['val_loss'], 'g-',label='Total Val Loss')
plt.plot(x, history.history['val_opt_loss'], 'g:',label='OPT Val Loss')
plt.plot(x, history.history['val_sar_loss'], 'g--',label='SAR Val Loss')
plt.plot(x, history.history['val_fusion_loss'], 'g-.',label='FUSION Val Loss')

plt.title('Training Loss')
plt.ylabel('Loss')
plt.xlabel('epoch')
plt.legend(loc='upper right')
plt.savefig('graphics/Loss.png')
plt.show()
```

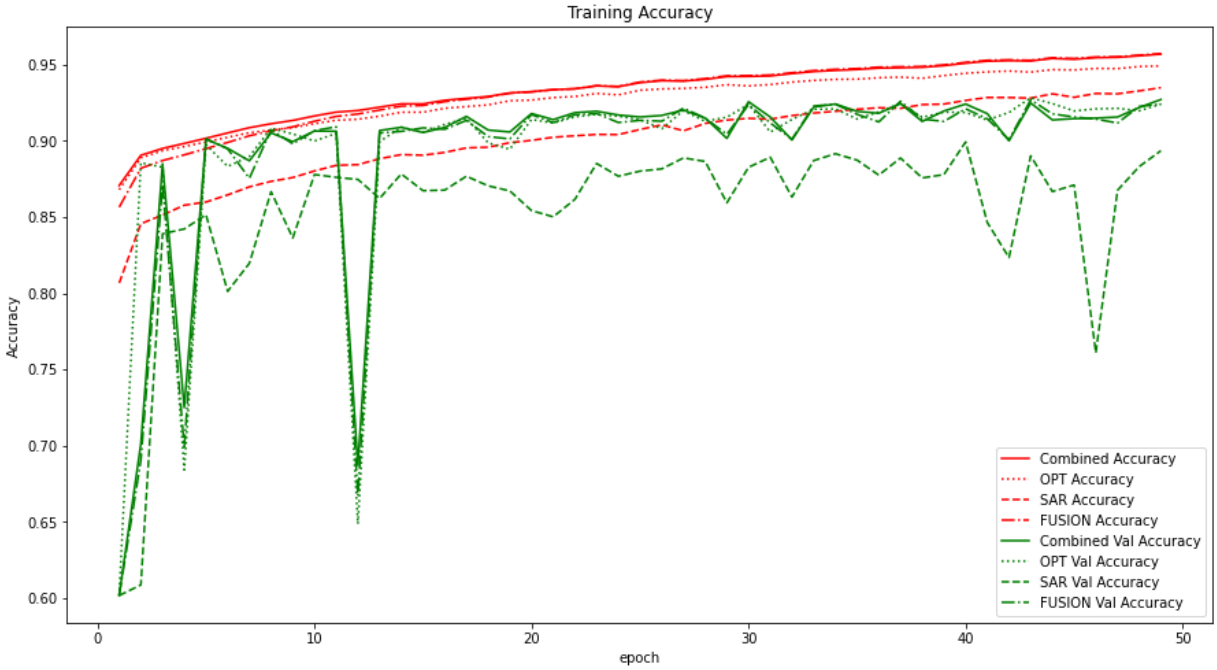
In [8]:

```
plt.figure(figsize=(15, 8))
x = np.arange(len(history.history['loss']))+1
plt.plot(x, history.history['combined_accuracy'], 'r-',label='Combined Accuracy')
plt.plot(x, history.history['opt_accuracy'], 'r:',label='OPT Accuracy')
plt.plot(x, history.history['sar_accuracy'], 'r--',label='SAR Accuracy')
plt.plot(x, history.history['fusion_accuracy'], 'r-.',label='FUSION Accuracy')

plt.plot(x, history.history['val_combined_accuracy'], 'g-',label='Combined Val Accur
plt.plot(x, history.history['val_opt_accuracy'], 'g:',label='OPT Val Accuracy')
plt.plot(x, history.history['val_sar_accuracy'], 'g--',label='SAR Val Accuracy')
plt.plot(x, history.history['val_fusion_accuracy'], 'g-.',label='FUSION Val Accuracy

plt.title('Training Accuracy')
plt.ylabel('Accuracy')
plt.xlabel('epoch')
plt.legend(loc='lower right')
```

```
plt.savefig('graphics/Accuracy.png')
plt.show()
```

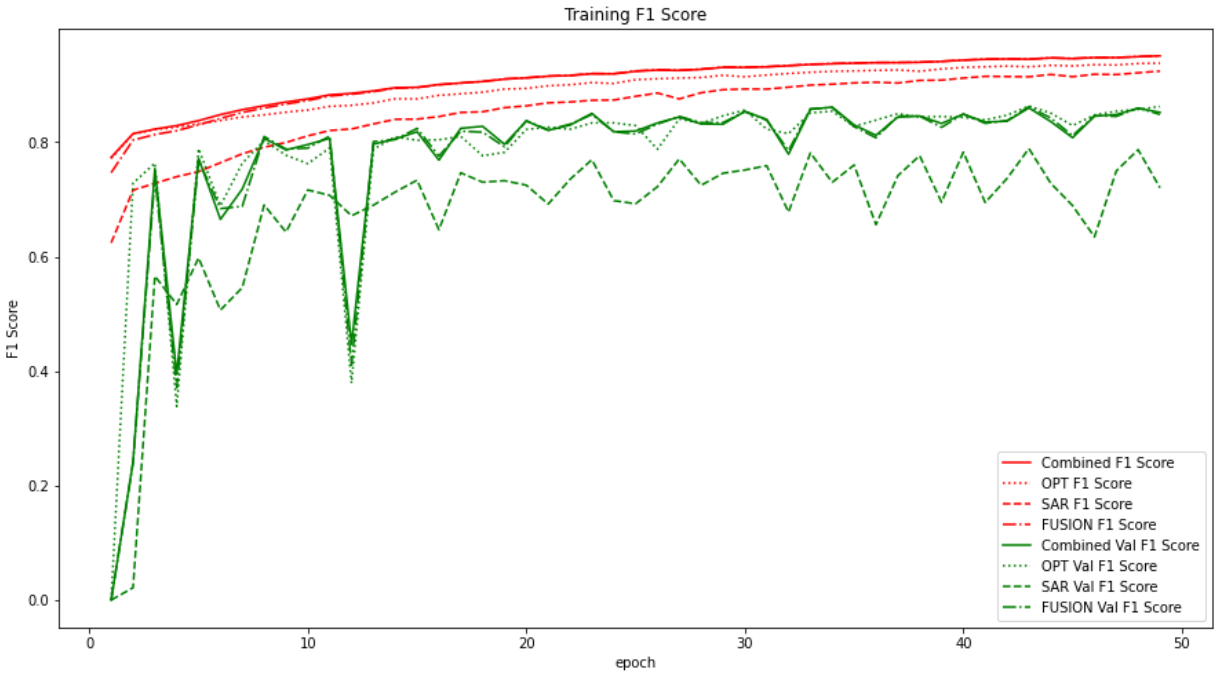


In [9]:

```
plt.figure(figsize=(15, 8))
x = np.arange(len(history.history['loss']))+1
plt.plot(x, history.history['combined_f1score'], 'r-',label='Combined F1 Score')
plt.plot(x, history.history['opt_f1score'], 'r:',label='OPT F1 Score')
plt.plot(x, history.history['sar_f1score'], 'r--',label='SAR F1 Score')
plt.plot(x, history.history['fusion_f1score'], 'r-.',label='FUSION F1 Score')

plt.plot(x, history.history['val_combined_f1score'], 'g-',label='Combined Val F1 Sco
plt.plot(x, history.history['val_opt_f1score'], 'g:',label='OPT Val F1 Score')
plt.plot(x, history.history['val_sar_f1score'], 'g--',label='SAR Val F1 Score')
plt.plot(x, history.history['val_fusion_f1score'], 'g-.',label='FUSION Val F1 Score'

plt.title('Training F1 Score')
plt.ylabel('F1 Score')
plt.xlabel('epoch')
plt.legend(loc='lower right')
plt.savefig('graphics/F1score.png')
plt.show()
```



Evaluation

In [10]:

```
opt_avg_prec_list = []
sar_avg_prec_list = []
fusion_avg_prec_list = []
combined_avg_prec_list = []


pred_path = params_patches['pred_path']
shutil.rmtree(pred_path, ignore_errors=True)
os.makedirs(pred_path)


for tile_n in params_patches['test_tiles']:
    dl_test.set_tile(int(tile_n))

    shape_tile = shapes_json[str(tile_n)]

    y_true = np.load(os.path.join(params_patches['tiles_path'], params_patches['labe
    y_true = to_categorical(y_true, 3)

    predictions_opt = []
    predictions_sar = []
    predictions_fusion = []
    predictions_combined = []

    for batch in tqdm(range(len(dl_test))):
        pred = model.predict_on_batch(dl_test[batch][0])
        predictions_opt.append(pred[0])
        predictions_sar.append(pred[1])
        predictions_fusion.append(pred[2])
        predictions_combined.append(pred[3])

    predictions_opt = np.concatenate(predictions_opt, axis=0)
    predictions_sar = np.concatenate(predictions_sar, axis=0)
    predictions_fusion = np.concatenate(predictions_fusion, axis=0)
    predictions_combined = np.concatenate(predictions_combined, axis=0)

    predictions_opt_rec = reconstruct_image(predictions_opt, params_patches['patch_s
    predictions_sar_rec = reconstruct_image(predictions_sar, params_patches['patch_s
    predictions_fusion_rec = reconstruct_image(predictions_fusion, params_patches['p
```

```
    predictions_combined_rec = reconstruct_image(predictions_combined, params_patche

    np.save(os.path.join(params_patches['pred_path'], f'pred_opt_{tile_n:02d}.npy'),
    np.save(os.path.join(params_patches['pred_path'], f'pred_sar_{tile_n:02d}.npy'),
    np.save(os.path.join(params_patches['pred_path'], f'pred_fusion_{tile_n:02d}.npy
    np.save(os.path.join(params_patches['pred_path'], f'pred_combined_{tile_n:02d}.n

    opt_avg_prec = average_precision_score(y_true[:, :, 1].flatten(), predictions_op
    sar_avg_prec = average_precision_score(y_true[:, :, 1].flatten(), predictions_sa
    fusion_avg_prec = average_precision_score(y_true[:, :, 1].flatten(), predictions
    combined_avg_prec = average_precision_score(y_true[:, :, 1].flatten(), predictio

    opt_avg_prec_list.append(opt_avg_prec)
    sar_avg_prec_list.append(sar_avg_prec)
    fusion_avg_prec_list.append(fusion_avg_prec)
    combined_avg_prec_list.append(combined_avg_prec)

    print(f'Precision Average (Class 1) of OPT prediction of tile {tile_n} is {opt_a
    print(f'Precision Average (Class 1) of SAR prediction of tile {tile_n} is {sar_a
    print(f'Precision Average (Class 1) of FUSION prediction of tile {tile_n} is {fu
    print(f'Precision Average (Class 1) of COMBINED prediction of tile {tile_n} is {

    opt_avg_prec = average_precision_score(y_true[:, :, 0].flatten(), predictions_op
    sar_avg_prec = average_precision_score(y_true[:, :, 0].flatten(), predictions_sa
    fusion_avg_prec = average_precision_score(y_true[:, :, 0].flatten(), predictions
    combined_avg_prec = average_precision_score(y_true[:, :, 0].flatten(), predictio

    print(f'Precision Average (Class 0) of OPT prediction of tile {tile_n} is {opt_a
    print(f'Precision Average (Class 0) of SAR prediction of tile {tile_n} is {sar_a
    print(f'Precision Average (Class 0) of FUSION prediction of tile {tile_n} is {fu
    print(f'Precision Average (Class 0) of COMBINED prediction of tile {tile_n} is {
```

```
100%|██████████| 558/558 [02:30<00:00,  3.71it/s]
Precision Average (Class 1) of OPT prediction of tile 2 is 0.7533
Precision Average (Class 1) of SAR prediction of tile 2 is 0.5518
Precision Average (Class 1) of FUSION prediction of tile 2 is 0.7627
Precision Average (Class 1) of COMBINED prediction of tile 2 is 0.7739
Precision Average (Class 0) of OPT prediction of tile 2 is 0.9694
Precision Average (Class 0) of SAR prediction of tile 2 is 0.9484
Precision Average (Class 0) of FUSION prediction of tile 2 is 0.9704
Precision Average (Class 0) of COMBINED prediction of tile 2 is 0.9675
100%|██████████| 558/558 [02:31<00:00,  3.68it/s]
Precision Average (Class 1) of OPT prediction of tile 4 is 0.6777
Precision Average (Class 1) of SAR prediction of tile 4 is 0.4842
Precision Average (Class 1) of FUSION prediction of tile 4 is 0.6908
Precision Average (Class 1) of COMBINED prediction of tile 4 is 0.7009
Precision Average (Class 0) of OPT prediction of tile 4 is 0.9703
Precision Average (Class 0) of SAR prediction of tile 4 is 0.9469
Precision Average (Class 0) of FUSION prediction of tile 4 is 0.9731
Precision Average (Class 0) of COMBINED prediction of tile 4 is 0.9712
100%|██████████| 558/558 [02:27<00:00,  3.77it/s]
Precision Average (Class 1) of OPT prediction of tile 5 is 0.7688
Precision Average (Class 1) of SAR prediction of tile 5 is 0.6097
Precision Average (Class 1) of FUSION prediction of tile 5 is 0.7883
Precision Average (Class 1) of COMBINED prediction of tile 5 is 0.7843
Precision Average (Class 0) of OPT prediction of tile 5 is 0.9796
Precision Average (Class 0) of SAR prediction of tile 5 is 0.9630
Precision Average (Class 0) of FUSION prediction of tile 5 is 0.9814
Precision Average (Class 0) of COMBINED prediction of tile 5 is 0.9813
100%|██████████| 558/558 [02:31<00:00,  3.67it/s]
Precision Average (Class 1) of OPT prediction of tile 9 is 0.7407
Precision Average (Class 1) of SAR prediction of tile 9 is 0.5899
Precision Average (Class 1) of FUSION prediction of tile 9 is 0.7665
```

```
Precision Average (Class 1) of COMBINED prediction of tile 9 is 0.7577
Precision Average (Class 0) of OPT prediction of tile 9 is 0.9940
Precision Average (Class 0) of SAR prediction of tile 9 is 0.8124
Precision Average (Class 0) of FUSION prediction of tile 9 is 0.9915
Precision Average (Class 0) of COMBINED prediction of tile 9 is 0.9779
100%|██████████| 558/558 [02:21<00:00,  3.96it/s]
Precision Average (Class 1) of OPT prediction of tile 10 is 0.7993
Precision Average (Class 1) of SAR prediction of tile 10 is 0.4715
Precision Average (Class 1) of FUSION prediction of tile 10 is 0.8011
Precision Average (Class 1) of COMBINED prediction of tile 10 is 0.7910
Precision Average (Class 0) of OPT prediction of tile 10 is 0.9840
Precision Average (Class 0) of SAR prediction of tile 10 is 0.9661
Precision Average (Class 0) of FUSION prediction of tile 10 is 0.9851
Precision Average (Class 0) of COMBINED prediction of tile 10 is 0.9833
100%|██████████| 558/558 [02:26<00:00,  3.81it/s]
Precision Average (Class 1) of OPT prediction of tile 11 is 0.4996
Precision Average (Class 1) of SAR prediction of tile 11 is 0.0821
Precision Average (Class 1) of FUSION prediction of tile 11 is 0.4758
Precision Average (Class 1) of COMBINED prediction of tile 11 is 0.4428
Precision Average (Class 0) of OPT prediction of tile 11 is 0.9613
Precision Average (Class 0) of SAR prediction of tile 11 is 0.9385
Precision Average (Class 0) of FUSION prediction of tile 11 is 0.9634
Precision Average (Class 0) of COMBINED prediction of tile 11 is 0.9623
100%|██████████| 558/558 [02:16<00:00,  4.08it/s]
Precision Average (Class 1) of OPT prediction of tile 13 is 0.6232
Precision Average (Class 1) of SAR prediction of tile 13 is 0.2304
Precision Average (Class 1) of FUSION prediction of tile 13 is 0.6127
Precision Average (Class 1) of COMBINED prediction of tile 13 is 0.5309
Precision Average (Class 0) of OPT prediction of tile 13 is 0.9764
Precision Average (Class 0) of SAR prediction of tile 13 is 0.9047
Precision Average (Class 0) of FUSION prediction of tile 13 is 0.9771
Precision Average (Class 0) of COMBINED prediction of tile 13 is 0.9696
100%|██████████| 558/558 [02:10<00:00,  4.28it/s]
Precision Average (Class 1) of OPT prediction of tile 15 is 0.2193
Precision Average (Class 1) of SAR prediction of tile 15 is 0.0707
Precision Average (Class 1) of FUSION prediction of tile 15 is 0.3051
Precision Average (Class 1) of COMBINED prediction of tile 15 is 0.2756
Precision Average (Class 0) of OPT prediction of tile 15 is 0.9879
Precision Average (Class 0) of SAR prediction of tile 15 is 0.7024
Precision Average (Class 0) of FUSION prediction of tile 15 is 0.9857
Precision Average (Class 0) of COMBINED prediction of tile 15 is 0.9787
100%|██████████| 558/558 [02:14<00:00,  4.14it/s]
Precision Average (Class 1) of OPT prediction of tile 18 is 0.9318
Precision Average (Class 1) of SAR prediction of tile 18 is 0.7533
Precision Average (Class 1) of FUSION prediction of tile 18 is 0.9396
Precision Average (Class 1) of COMBINED prediction of tile 18 is 0.9363
Precision Average (Class 0) of OPT prediction of tile 18 is 0.9323
Precision Average (Class 0) of SAR prediction of tile 18 is 0.3760
Precision Average (Class 0) of FUSION prediction of tile 18 is 0.9231
Precision Average (Class 0) of COMBINED prediction of tile 18 is 0.8556
```

In [ ]: