cs2_model_evaluation

August 2, 2021

1 Libraries

[1]:

```
import warnings
warnings.filterwarnings('ignore')
import os
import sys
import numpy as np
import pandas as pd
from tqdm import tqdm
pd.set_option("display.max_colwidth", -1)
import cv2
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import seaborn as sns
import tensorflow as tf
```

[2]:

```
#seeding
seed = 2021
np.random.seed = seed
tf.seed = seed
```

[3]:

```
from google.colab import files
files.upload()
```

```
<IPython.core.display.HTML object>


Saving kaggle.json to kaggle.json
```

[3]:

```
{'kaggle.json':
b'{"username":"maksahu","key":"cff8c0f086aa6e0e50553f7ab0580687"}'}
```

[4]:

```
!mkdir -p ~/.kaggle
!cp kaggle.json ~/.kaggle/
!chmod 600 ~/.kaggle/kaggle.json
```

2 Data

[5]:

```
!kaggle competitions download -c data-science-bowl-2018
```

```
Warning: Looks like you're using an outdated API Version, please consider
updating (server 1.5.12 / client 1.5.4)
Downloading stage1_train_labels.csv.zip to /content
  0% 0.00/2.67M [00:00<?, ?B/s]
100% 2.67M/2.67M [00:00<00:00, 89.7MB/s]
Downloading stage1_test.zip to /content
 66% 6.00M/9.10M [00:00<00:00, 61.3MB/s]
100% 9.10M/9.10M [00:00<00:00, 58.3MB/s]
Downloading stage1_train.zip to /content
 83% 66.0M/79.1M [00:00<00:00, 79.7MB/s]
100% 79.1M/79.1M [00:00<00:00, 161MB/s]
Downloading stage1_solution.csv.zip to /content
  0% 0.00/386k [00:00<?, ?B/s]
100% 386k/386k [00:00<00:00, 119MB/s]
Downloading stage2_test_final.zip to /content
 96% 266M/276M [00:05<00:00, 72.0MB/s]
100% 276M/276M [00:05<00:00, 49.1MB/s]
Downloading stage1_sample_submission.csv.zip to /content
  0% 0.00/2.62k [00:00<?, ?B/s]
100% 2.62k/2.62k [00:00<00:00, 2.57MB/s]
Downloading stage2_sample_submission_final.csv.zip to /content
  0% 0.00/112k [00:00<?, ?B/s]
100% 112k/112k [00:00<00:00, 116MB/s]
```

[6]:

```
#Creating these two folder
!mkdir train test
```

[7]:

```
#Unziping the training and testing folders into directories
print('Unzipping stage1_train.zip')
!unzip -q "/content/stage1_train.zip" -d train/
print('Unzipped stage1_train.zip')

print('Unzipping stage1_test.zip')
!unzip -q "/content/stage1_train.zip" -d test/
print('Unzipped stage1_test.zip')
```

```
Unzipping stage1_train.zip
Unzipped stage1_train.zip
Unzipping stage1_test.zip
Unzipped stage1_test.zip
```

[8]:

```
# Root directories for training and testing
TRAIN_ROOT = './train'
TEST_ROOT = './test'
```

[9]:

```
# Function to create a dataframe of files which will be used for further␣
 ↪processing
def files_df(root_dir):
    subdir = os.listdir(root_dir)
    files = []
    df = pd.DataFrame()
    for dir in subdir:
        files.append(os.path.join(root_dir,dir))
    df['files'] = files
    return df
```

[10]:

```
train_df = files_df(TRAIN_ROOT)
test_df = files_df(TEST_ROOT)
```

[11]:

```
# Hyperparameters
IMG_WIDTH = 256
IMG_HEIGHT = 256
IMG_CHANNELS = 3
CLASSES = 1
BATCH_SIZE = 8
```

[12]:

```
# Function which will create a dataframe of image paths and mask paths along␣
 ↪with creating a single mask with multiple masks
def image_df(filenames):
    image_paths = []
    mask_paths = []
    df = pd.DataFrame()
    for filename in tqdm(filenames):
        file_path = os.path.join(filename,'images')
        image_path = os.path.join(file_path,os.listdir(file_path)[0])
        image_paths.append(image_path)

        mask = np.zeros((IMG_WIDTH,IMG_HEIGHT,CLASSES))
        mask_dir = file_path.replace("images", "masks")
        masks = os.listdir(mask_dir)
        for m in masks:
            mask_path = os.path.join(mask_dir,m)
            mask_  = cv2.imread(mask_path, cv2.IMREAD_UNCHANGED)
            mask_  = cv2.resize(mask_,(IMG_WIDTH,IMG_HEIGHT),interpolation=cv2.
 ↪INTER_NEAREST)
            mask_  = np.expand_dims(mask_, axis = -1)
            mask = np.maximum(mask,mask_)
        newmask_dir = mask_dir.replace("masks", "masks_")
        if not os.path.isdir(newmask_dir):
            os.mkdir(newmask_dir)
        newmask_path = image_path.replace("images", "masks_")
        mask_paths.append(newmask_path)
        cv2.imwrite(newmask_path, mask)
    df['images'] = image_paths
    df['masks'] = mask_paths
    return df
```

[13]:

```
# Training dataframe
train_filenames = train_df['files']
train = image_df(train_filenames)
```

```
100%|     | 670/670 [00:26<00:00, 24.85it/s]
```

[14]:

```
train.head()
```

[14]:

```
                                                                  images
masks
0  ./train/b4de1e3eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db/imag
es/b4de1e3eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db.png  ./train
/b4de1e3eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db/masks_/b4de1e3
eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db.png
1  ./train/e414b54f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c/imag
es/e414b54f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c.png  ./train
/e414b54f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c/masks_/e414b54
f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c.png
2  ./train/5afb7932e9c7328f4fb1d7a8166a3699d6cdc5192b93758a75e9956f1513c5a3/imag
es/5afb7932e9c7328f4fb1d7a8166a3699d6cdc5192b93758a75e9956f1513c5a3.png  ./train
/5afb7932e9c7328f4fb1d7a8166a3699d6cdc5192b93758a75e9956f1513c5a3/masks_/5afb793
2e9c7328f4fb1d7a8166a3699d6cdc5192b93758a75e9956f1513c5a3.png
3  ./train/ef6634efb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6/imag
es/ef6634efb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6.png  ./train
/ef6634efb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6/masks_/ef6634e
fb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6.png
4  ./train/2c840a94d216f5ef4e499b53ae885e9b022cbf639e004ec788436093837823b2/imag
es/2c840a94d216f5ef4e499b53ae885e9b022cbf639e004ec788436093837823b2.png  ./train
/2c840a94d216f5ef4e499b53ae885e9b022cbf639e004ec788436093837823b2/masks_/2c840a9
4d216f5ef4e499b53ae885e9b022cbf639e004ec788436093837823b2.png
```

[15]:

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

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

[16]:

```
unet_model = tf.keras.models.load_model("/content/drive/MyDrive/CaseStudy2/
 ↪unet_model.h5")
hrnet_model = tf.keras.models.load_model("/content/drive/MyDrive/CaseStudy2/
 ↪hrnet_model.h5")
```

3 EDA

[17]:

```
# Custom MeanIoU Metric function
class MeanIoU(tf.keras.metrics.Metric):
    def __init__(self, num_classes, thres=0.5, name='mean_iou', dtype=None):
        super(MeanIoU, self).__init__(name=name, dtype=dtype)
        self.num_classes = num_classes
        self.thres = thres
        self.total_cm = self.add_weight('total_confusion_matrix',
                                        shape=(num_classes, num_classes),
                                        initializer=tf.zeros_initializer())

    def update_state(self, y_true, y_pred, sample_weight=None):

        y_true = tf.cast(y_true, self._dtype)
        y_pred = tf.cast(y_pred, self._dtype)
        if y_pred.shape.ndims > 1:
            y_pred = tf.reshape(y_pred, [-1])
        if y_true.shape.ndims > 1:
            y_true = tf.reshape(y_true, [-1])

        y_pred = tf.where(y_pred > self.thres, 1.0, 0.0)

        if sample_weight is not None:
            sample_weight = tf.cast(sample_weight, self._dtype)
            if sample_weight.shape.ndims > 1:
                sample_weight = tf.reshape(sample_weight, [-1])
        current_cm = tf.math.confusion_matrix(y_true,
                                              y_pred,
                                              self.num_classes,
                                              weights=sample_weight,
                                              dtype=self._dtype)

        return self.total_cm.assign_add(current_cm)

    def result(self):
        sum_over_row = tf.cast(tf.reduce_sum(self.total_cm, axis=0), dtype=self.
 ↪_dtype)
        sum_over_col = tf.cast(tf.reduce_sum(self.total_cm, axis=1), dtype=self.
 ↪_dtype)
        true_positives = tf.cast(tf.linalg.tensor_diag_part(self.total_cm),␣
 ↪dtype=self._dtype)
        denominator = sum_over_row + sum_over_col - true_positives
        num_valid_entries = tf.reduce_sum(tf.cast(tf.math.
 ↪not_equal(denominator, 0), dtype=self._dtype))
        iou = tf.math.divide_no_nan(true_positives, denominator)
        return tf.math.divide_no_nan(tf.reduce_sum(iou, name='mean_iou'),␣
↪num_valid_entries)

    def reset_states(self):
        # The state of the metric will be reset at the start of each epoch.
        tf.keras.backend.set_value(self.total_cm, np.zeros((self.num_classes,␣
↪self.num_classes)))

    def get_config(self):
        config = {'num_classes': self.num_classes}
        base_config = super(MeanIoU, self).get_config()
        return dict(list(base_config.items()) + list(config.items()))
```

[18]:

```
# Function to create a dataframe with iou_scores for each model and image and␣
↪mask paths.
def metric_df(data):
    unet_iou_scores = []
    hrnet_iou_scores = []
    m = MeanIoU(2, 0.4)
    for i in tqdm(range(len(data))):

        image_path = data['images'].iloc[i]
        mask_path = data['masks'].iloc[i]
        image_string = tf.io.read_file(image_path)
        image = tf.image.decode_png(image_string, channels=IMG_CHANNELS)#
        image = tf.image.convert_image_dtype(image, tf.float32)
        image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH]) # height x width

        mask_string = tf.io.read_file(mask_path)
        mask = tf.image.decode_png(mask_string, channels=CLASSES)#
        mask = tf.image.convert_image_dtype(mask, tf.float32)
        mask = tf.image.resize(mask, [IMG_HEIGHT, IMG_WIDTH])

        pred_mask_u = unet_model.predict(image[np.newaxis,:,:,:])
        m.update_state(mask, pred_mask_u)
        u_iou_score = m.result().numpy()
        unet_iou_scores.append(round(u_iou_score,4))

        pred_mask_h = hrnet_model.predict(image[np.newaxis,:,:,:])
        m.update_state(mask, pred_mask_h)
        h_iou_score = m.result().numpy()
        hrnet_iou_scores.append(round(h_iou_score,4))


    data['unet_iou_scores'] = unet_iou_scores
    data['hrnet_iou_scores'] = hrnet_iou_scores
    return data
```

[19]:

```python
df = train.copy()
df = metric_df(df)
df = df.sort_values(by=['hrnet_iou_scores','unet_iou_scores'])
df.head()
```

```
100%|     | 670/670 [02:14<00:00,  5.00it/s]
```

[19]:

```
                                                                 images  …
hrnet_iou_scores
3   ./train/ef6634efb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6/ima
ges/ef6634efb46567d87b811be786b18c4cd0e2cda23d79b65d6afe0d259ef3ade6.png  …
0.9151
8   ./train/44ab6a09eedee848b072ea3acd0f4e781f9c43b8d4e3d62598e1024584bf0b01/ima
ges/44ab6a09eedee848b072ea3acd0f4e781f9c43b8d4e3d62598e1024584bf0b01.png  …
0.9165
6   ./train/4d14a3629b6af6de86d850be236b833a7bfcbf6d8665fd73c6dc339e06c14607/ima
ges/4d14a3629b6af6de86d850be236b833a7bfcbf6d8665fd73c6dc339e06c14607.png  …
0.9165
14  ./train/a9d884ba0929dac87c2052ce5b15034163685317d7cff45c40b0f7bd9bd4d9e7/ima
ges/a9d884ba0929dac87c2052ce5b15034163685317d7cff45c40b0f7bd9bd4d9e7.png  …
0.9179
15  ./train/212b858a66f0d23768b8e3e1357704fc2f4cf4bbe7eed8cd59b5d01031d553e6/ima
ges/212b858a66f0d23768b8e3e1357704fc2f4cf4bbe7eed8cd59b5d01031d553e6.png  …
0.9182

[5 rows x 4 columns]
```

[20]:

```python
df.tail()
```

[20]:

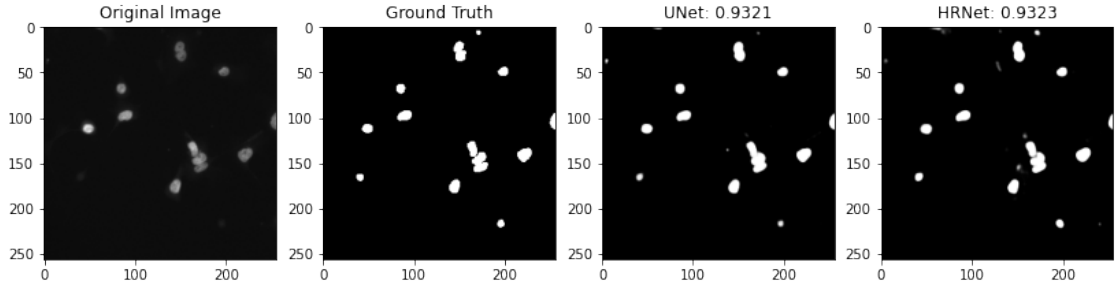
```
                                                                 images  …
hrnet_iou_scores
32  ./train/97158b2fe38783d88d4e44ba1b7bc6c84f225f8b35fcccc2f9265c65f14e7c8b/ima
ges/97158b2fe38783d88d4e44ba1b7bc6c84f225f8b35fcccc2f9265c65f14e7c8b.png  …
0.9323
33  ./train/673baf65ae5c571d6be452eb41e79ef3fc2eb3fd238e621c6b7621763b429989/ima
ges/673baf65ae5c571d6be452eb41e79ef3fc2eb3fd238e621c6b7621763b429989.png  …
0.9323
30  ./train/5bb8508ff8ec8683fc6a8aa6bd470f6feb3af4eccdca07f51a1ebc9dad67cfb8/ima
ges/5bb8508ff8ec8683fc6a8aa6bd470f6feb3af4eccdca07f51a1ebc9dad67cfb8.png  …
0.9326
1   ./train/e414b54f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c/ima
ges/e414b54f2036bcab61b9c0a966f65adf4b169097c13c740e03d6292ac076258c.png  …
0.9331
0   ./train/b4de1e3eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db/ima
ges/b4de1e3eec159d8af1bd5447696f8996c31709edaf33e26ba9613816705847db.png  …
0.9625
```

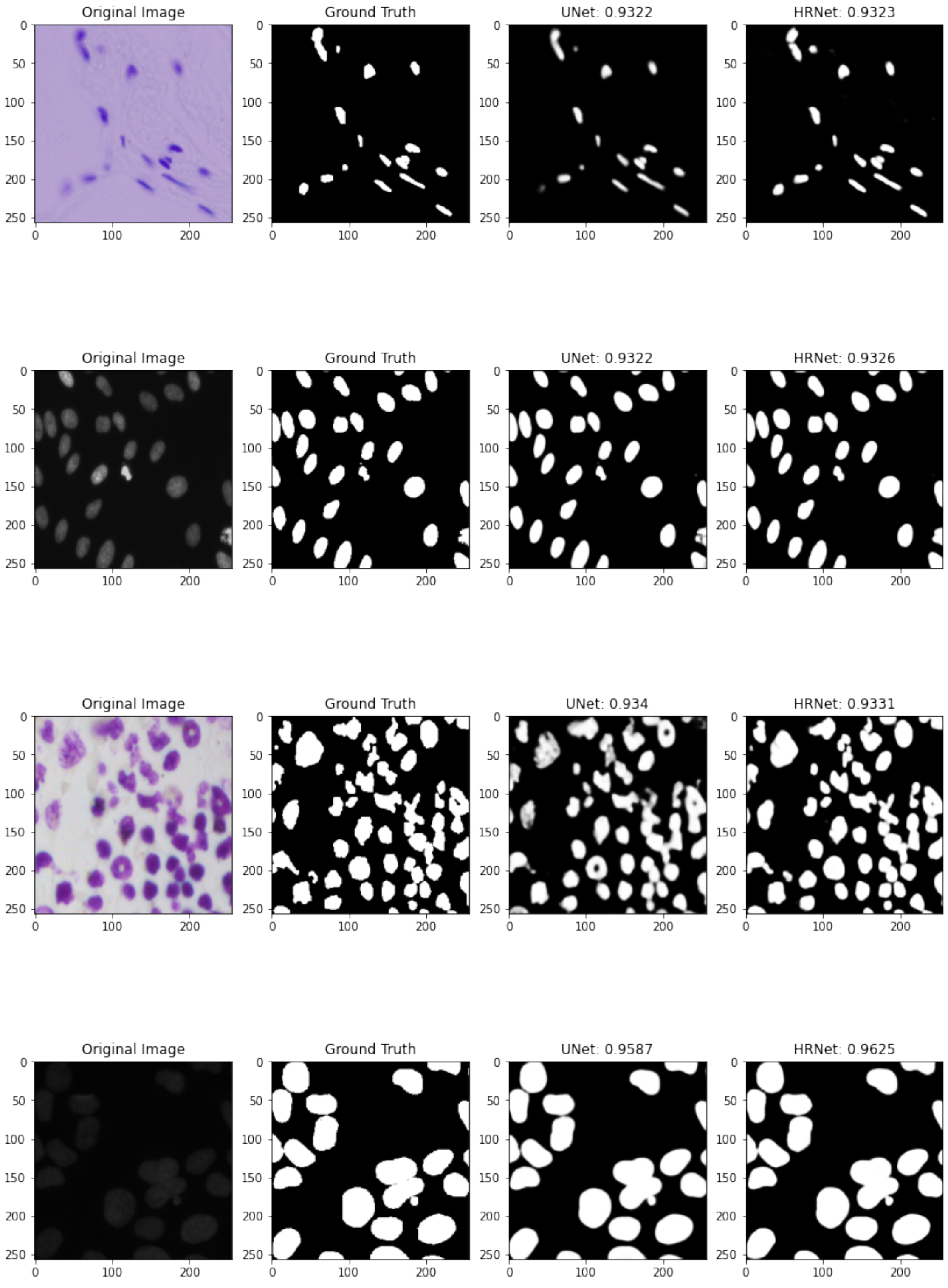
```
[5 rows x 4 columns]
```

3.1 Best Output samples

[21]:

```
d1 = df.tail()
for i in range(5):
    image_path = d1['images'].iloc[i]
    mask_path = d1['masks'].iloc[i]
    image_string = tf.io.read_file(image_path)
    image = tf.image.decode_png(image_string, channels=IMG_CHANNELS)#
    image = tf.image.convert_image_dtype(image, tf.float32)
    image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH]) # height x width

    mask_string = tf.io.read_file(mask_path)
    mask = tf.image.decode_png(mask_string, channels=CLASSES)#
    mask = tf.image.convert_image_dtype(mask, tf.float32)
    mask = tf.image.resize(mask, [IMG_HEIGHT, IMG_WIDTH])

    pred_mask_u  = unet_model.predict(image[np.newaxis,:,:,:])
    pred_mask_h  = hrnet_model.predict(image[np.newaxis,:,:,:])

    fig = plt.figure(figsize=(14,10))
    ax1 = fig.add_subplot(141)
    ax1.title.set_text('Original Image')
    ax1.imshow(image)
    ax2 = fig.add_subplot(142)
    ax2.title.set_text('Ground Truth')
    ax2.imshow(mask[:,:,0], cmap='gray')
    ax3 = fig.add_subplot(143)
    ax3.title.set_text('UNet: '+ str(round(d1['unet_iou_scores'].iloc[i],4)))
    ax3.imshow(pred_mask_u[0,:,:,0], cmap='gray')
    ax4 = fig.add_subplot(144)
    ax4.title.set_text('HRNet: '+ str(round(d1['hrnet_iou_scores'].iloc[i],4)))
    ax4.imshow(pred_mask_h[0,:,:,0], cmap='gray')
    plt.show()
```

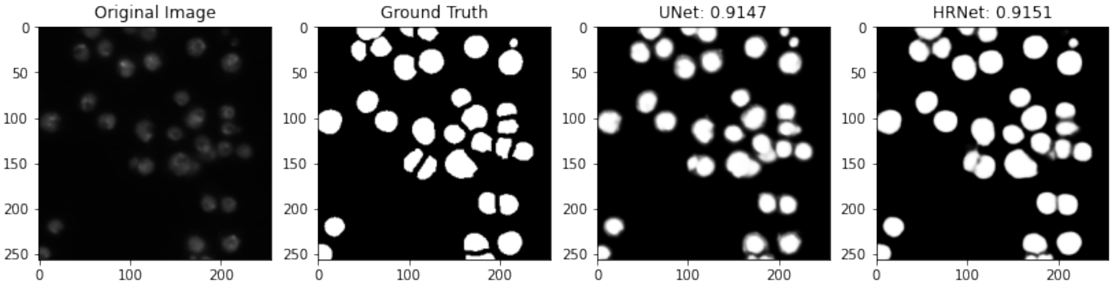


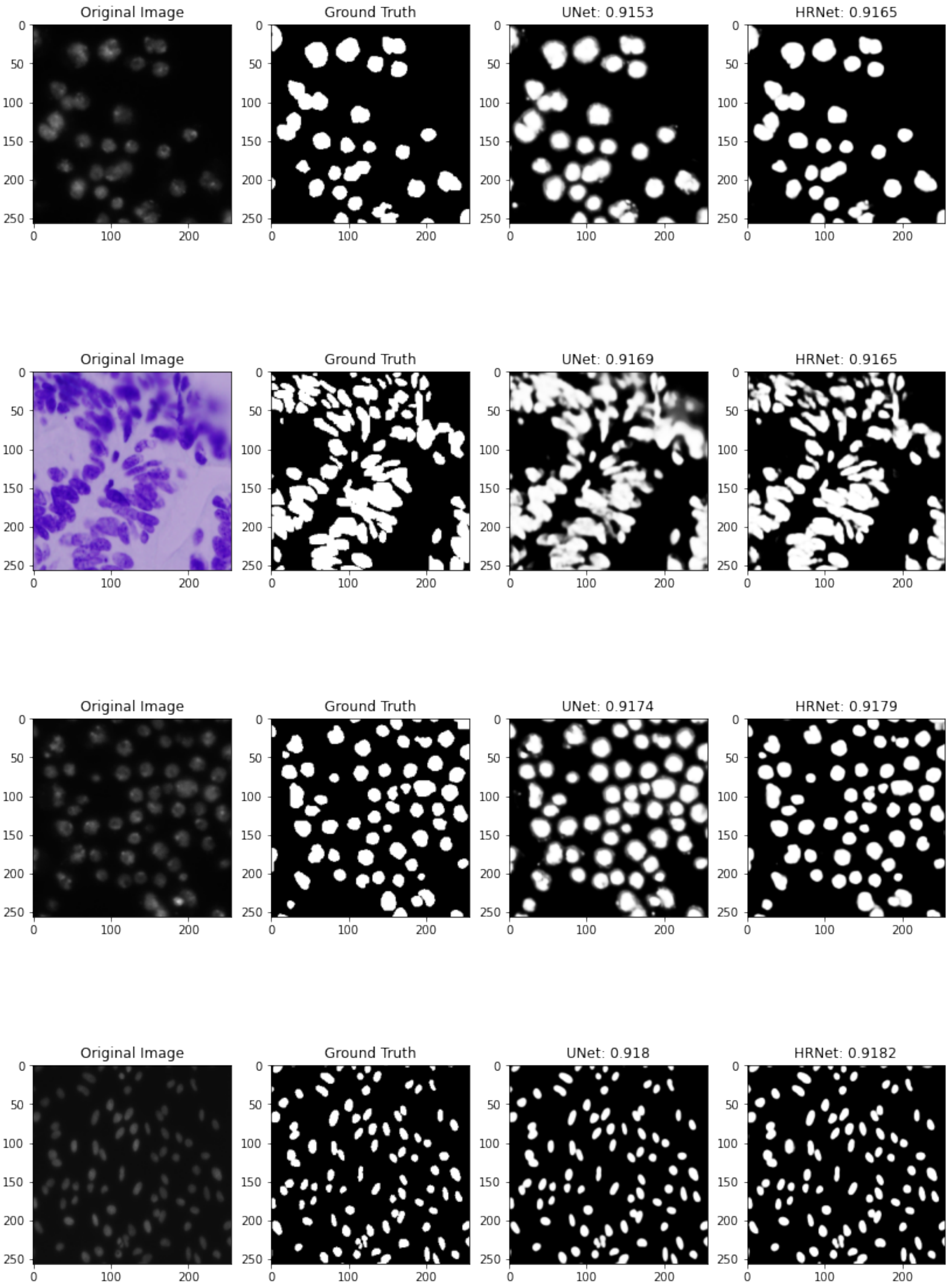

Original Image
Ground Truth
UNet: 0.9322
HRNet: 0.9323
Original Image
Ground Truth
UNet: 0.9322
HRNet: 0.9326
Original Image
Ground Truth
UNet: 0.934
HRNet: 0.9331
Original Image
Ground Truth
UNet: 0.9587
HRNet: 0.9625
0
50
100
150
200
250
0
100
200

3.2 Worst Output Samples

[22]:

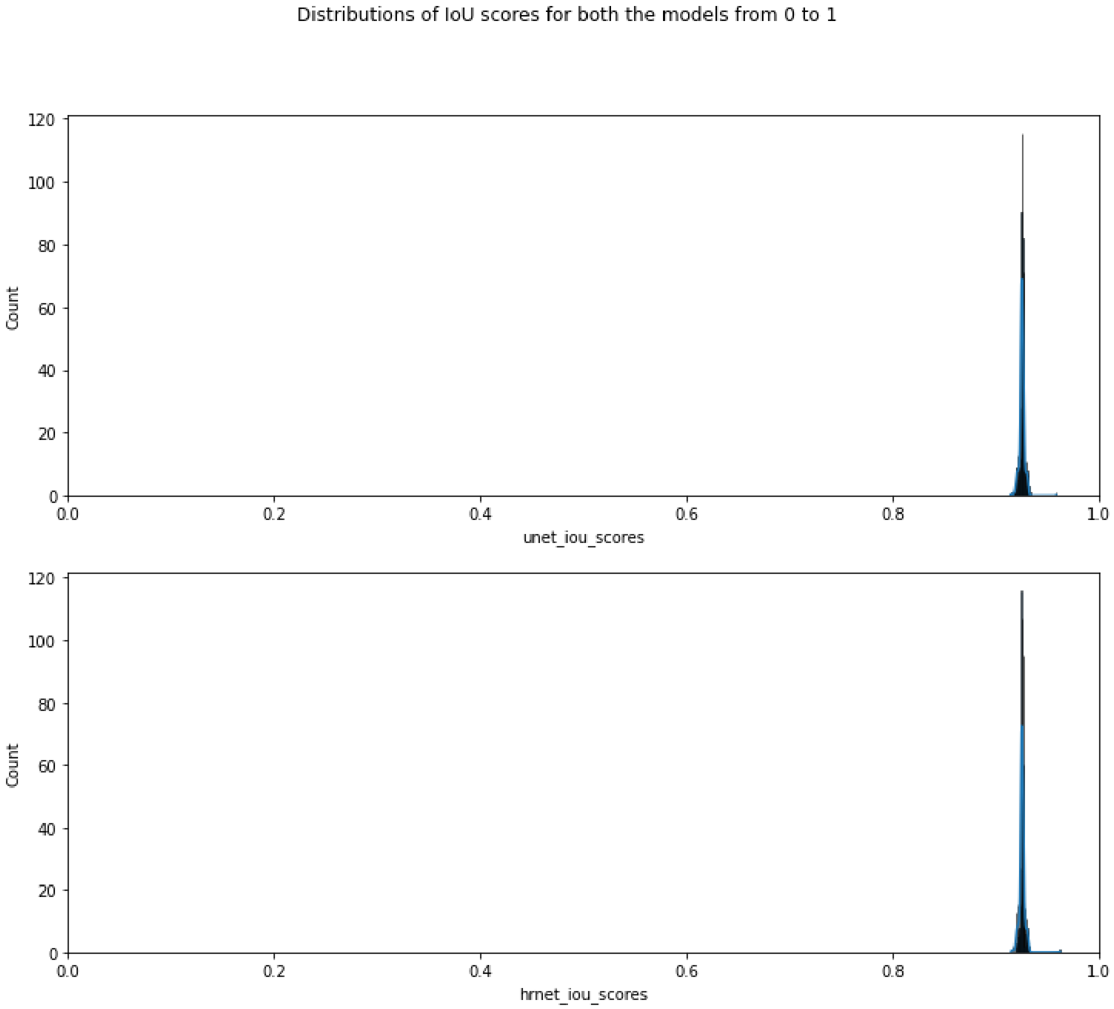
```
d2 = df.head()
for i in range(5):
    image_path = d2['images'].iloc[i]
    mask_path = d2['masks'].iloc[i]
    image_string = tf.io.read_file(image_path)
    image = tf.image.decode_png(image_string, channels=IMG_CHANNELS)#
    image = tf.image.convert_image_dtype(image, tf.float32)
    image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH]) # height x width

    mask_string = tf.io.read_file(mask_path)
    mask = tf.image.decode_png(mask_string, channels=CLASSES)#
    mask = tf.image.convert_image_dtype(mask, tf.float32)
    mask = tf.image.resize(mask, [IMG_HEIGHT, IMG_WIDTH])

    pred_mask_u  = unet_model.predict(image[np.newaxis,:,:,:])
    pred_mask_h  = hrnet_model.predict(image[np.newaxis,:,:,:])

    fig = plt.figure(figsize=(14,10))
    ax1 = fig.add_subplot(141)
    ax1.title.set_text('Original Image')
    ax1.imshow(image)
    ax2 = fig.add_subplot(142)
    ax2.title.set_text('Ground Truth')
    ax2.imshow(mask[:,:,0], cmap='gray')
    ax3 = fig.add_subplot(143)
    ax3.title.set_text('UNet: '+ str(round(d2['unet_iou_scores'].iloc[i],4)))
    ax3.imshow(pred_mask_u[0,:,:,0], cmap='gray')
    ax4 = fig.add_subplot(144)
    ax4.title.set_text('HRNet: '+ str(round(d2['hrnet_iou_scores'].iloc[i],4)))
    ax4.imshow(pred_mask_h[0,:,:,0], cmap='gray')
    plt.show()
```




Original Image
Ground Truth
UNet: 0.9153
HRNet: 0.9165
Original Image
Ground Truth
UNet: 0.9169
HRNet: 0.9165
Original Image
Ground Truth
UNet: 0.9174
HRNet: 0.9179
Original Image
Ground Truth
UNet: 0.918
HRNet: 0.9182
0
50
100
150
200
250
0
100
200

3.3 Distribution of 'iou_scores'

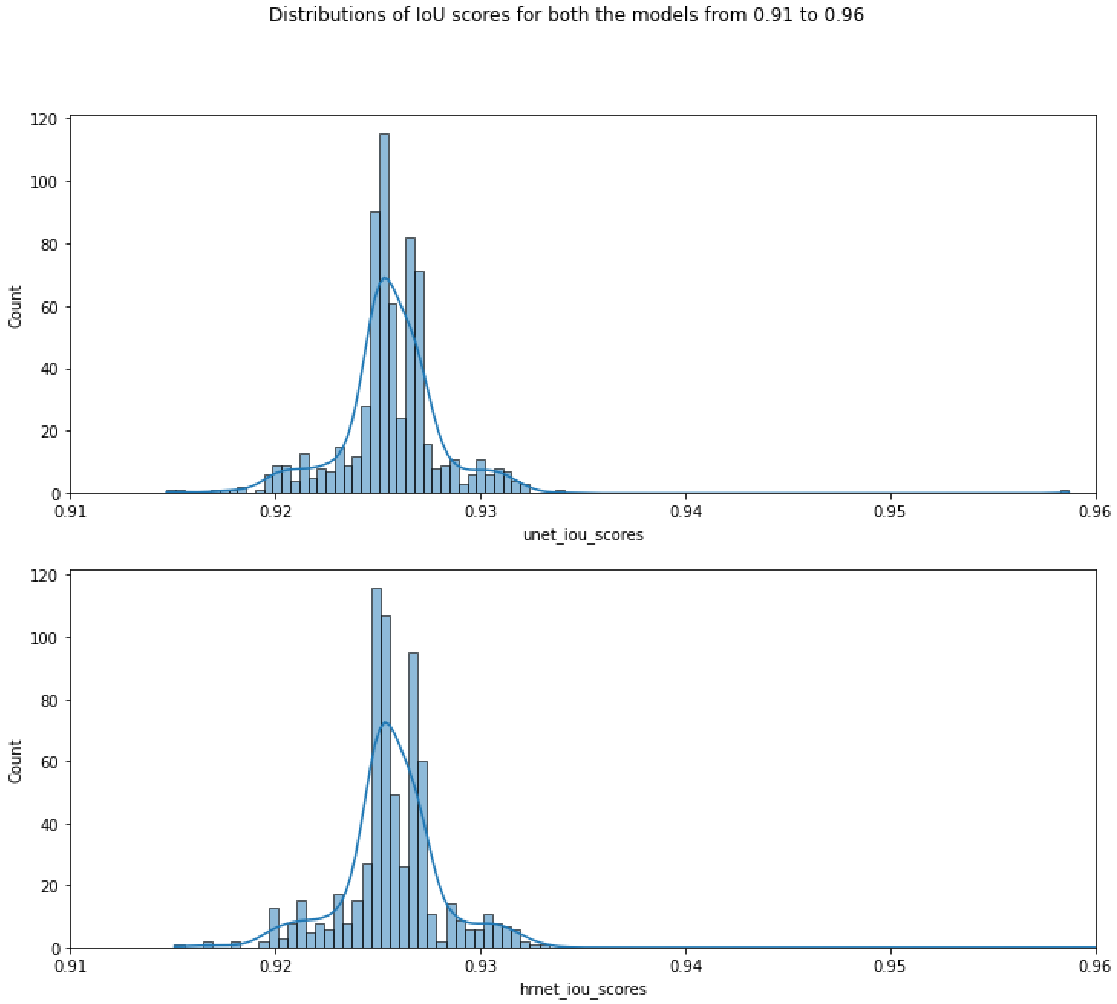
```
[23]: f, axes = plt.subplots(2, 1, figsize=(12,10))
      sns.histplot(data=df, x="unet_iou_scores",kde=True, ax=axes[0])
      sns.histplot(data=df, x="hrnet_iou_scores",kde=True, ax=axes[1])
      axes[0].set_xlim(0, 1)
      axes[1].set_xlim(0, 1)
      plt.suptitle("Distributions of IoU scores for both the models from 0 to 1")
      plt.show()
```



- The above plot is not providing much information.
- We will zoom it than.

```
[24]: f, axes = plt.subplots(2, 1, figsize=(12,10))
      sns.histplot(data=df, x="unet_iou_scores",kde=True, ax=axes[0])
      sns.histplot(data=df, x="hrnet_iou_scores",kde=True, ax=axes[1])
      axes[0].set_xlim(0.91, 0.96)
```

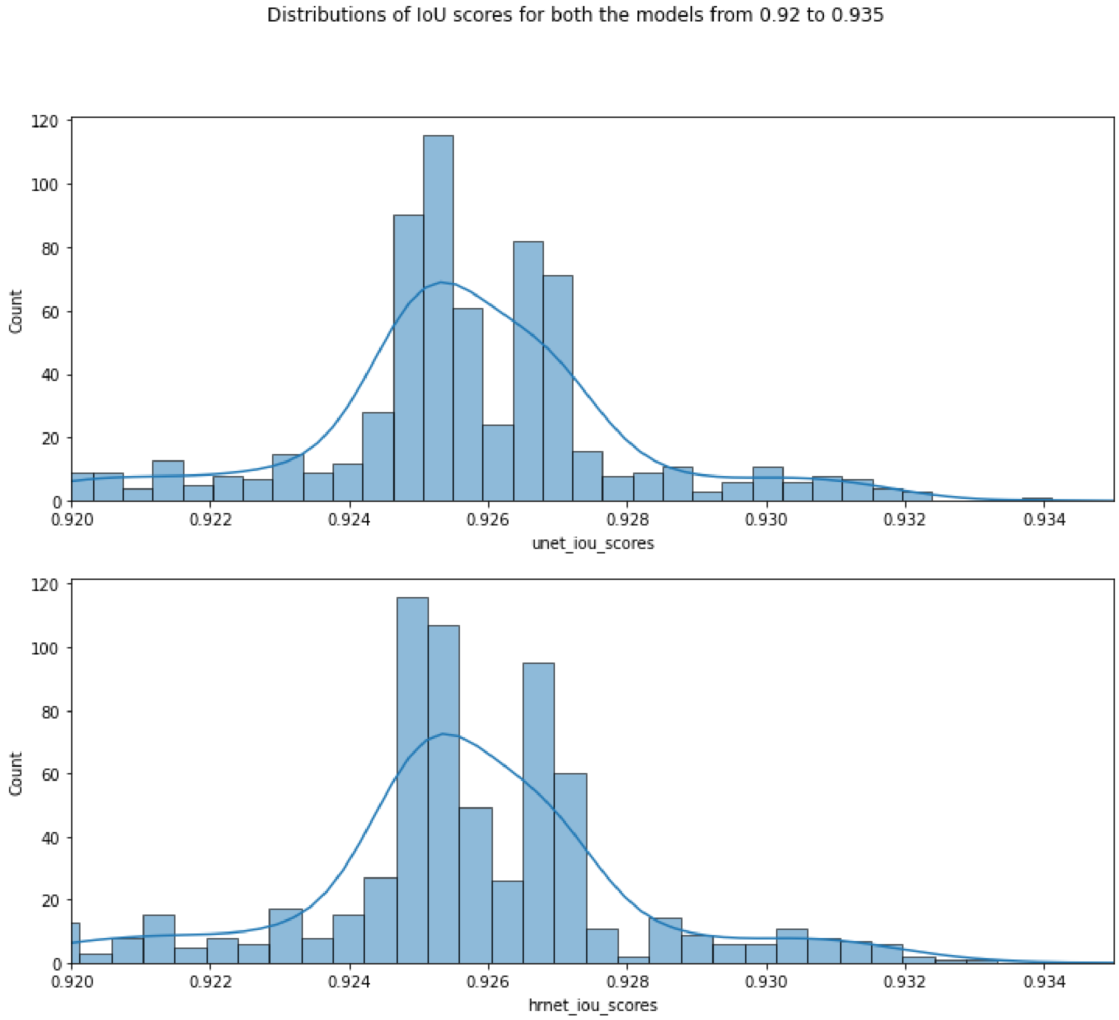
```
axes[1].set_xlim(0.91, 0.96)
plt.suptitle("Distributions of IoU scores for both the models from 0.91 to 0.
 ↪96")
plt.show()
```



- Above two plots seem almost identical.
- Points having iou score greater than 0.93 for the case of HRNet seems to be slightly more than UNet.

[25]:
```
f, axes = plt.subplots(2, 1, figsize=(12,10))
sns.histplot(data=df, x="unet_iou_scores",kde=True, ax=axes[0])
sns.histplot(data=df, x="hrnet_iou_scores",kde=True, ax=axes[1])
axes[0].set_xlim(0.92, 0.935)
axes[1].set_xlim(0.92, 0.935)
plt.suptitle("Distributions of IoU scores for both the models from 0.92 to 0.
 ↪935")
```

```
plt.show()
```



- From the above plot we can see that there are more points after 0.93 for the case of HRNet than UNet.

[26]:

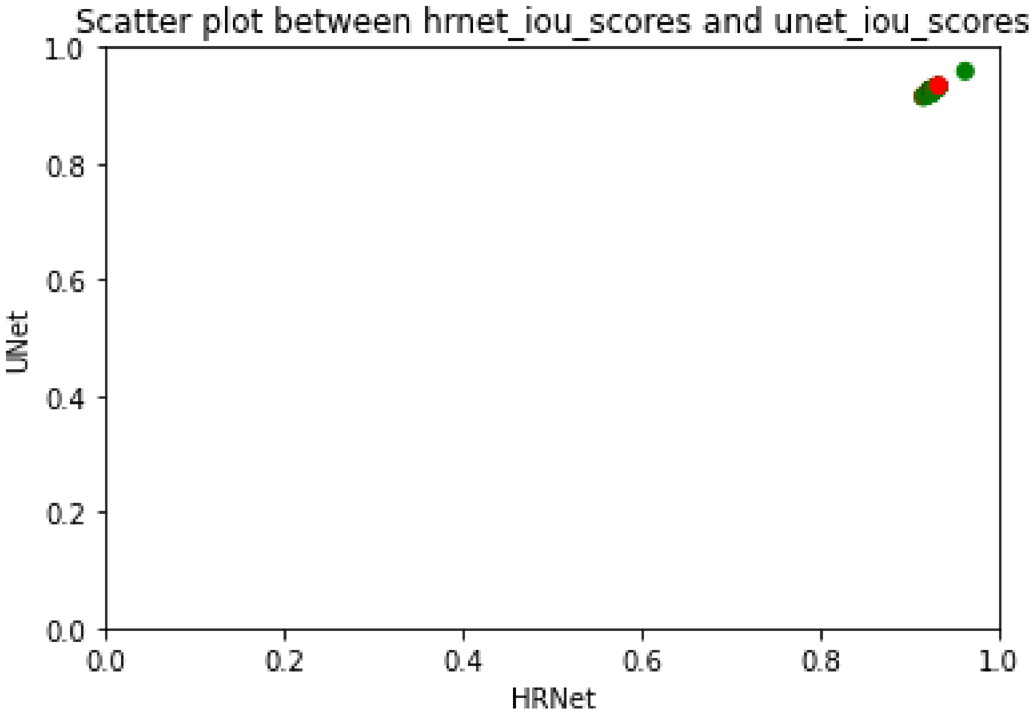
```
num_great = len(df[df['hrnet_iou_scores'] > df['unet_iou_scores']])
num_less = len(df[df['hrnet_iou_scores'] < df['unet_iou_scores']])
print('Number of points for which HRNet performed better: ', num_great)
print('Number of points for which UNet performed better: ', num_less)
```

```
Number of points for which HRNet performed better:  251
Number of points for which UNet performed better:  56
```

[27]:

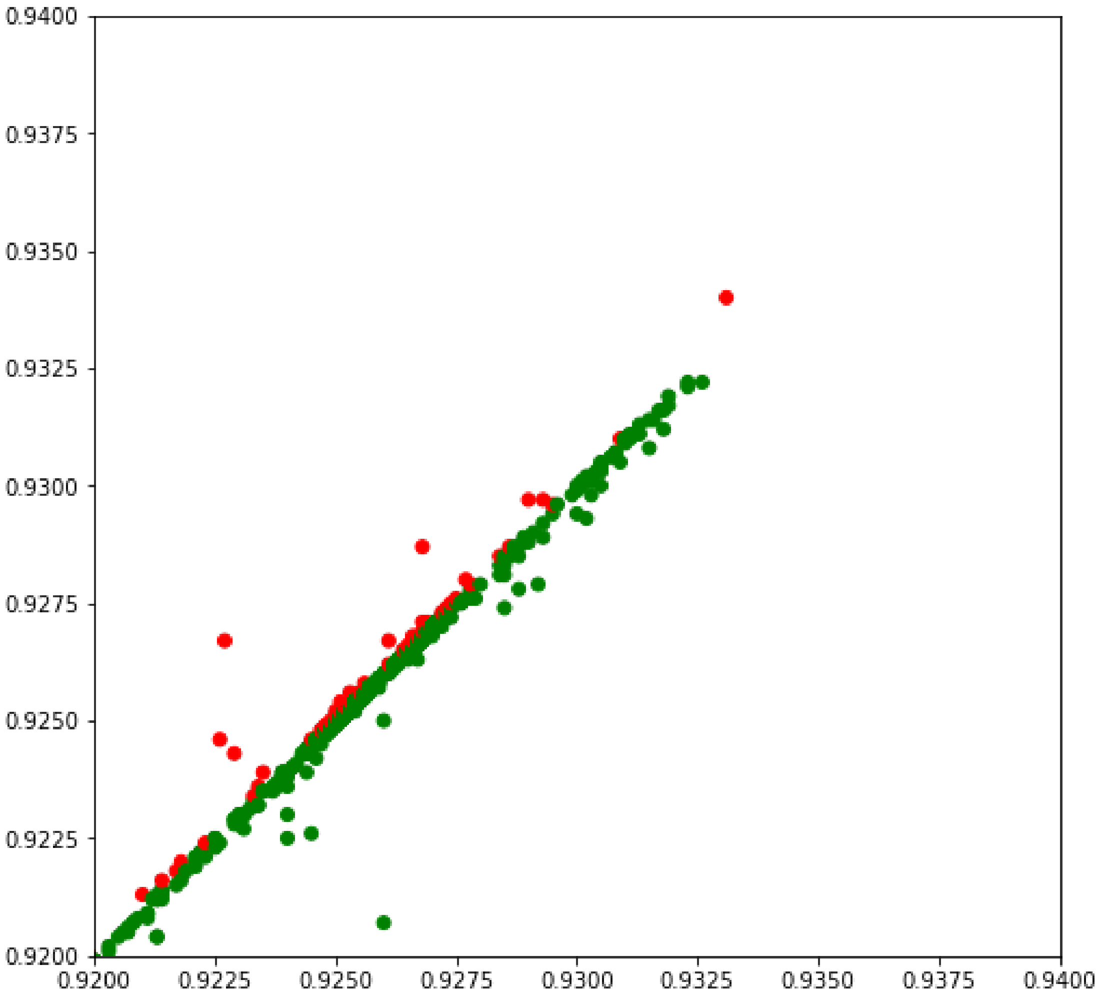
```
x = df['hrnet_iou_scores']
y = df['unet_iou_scores']
col = np.where(x<y,'red','green')
```

```
fig, ax = plt.subplots()
ax.scatter(x, y, c=col)
plt.xlim(0,1)
plt.ylim(0,1)
plt.xlabel('HRNet')
plt.ylabel('UNet')
plt.title('Scatter plot between hrnet_iou_scores and unet_iou_scores')
plt.show()
```



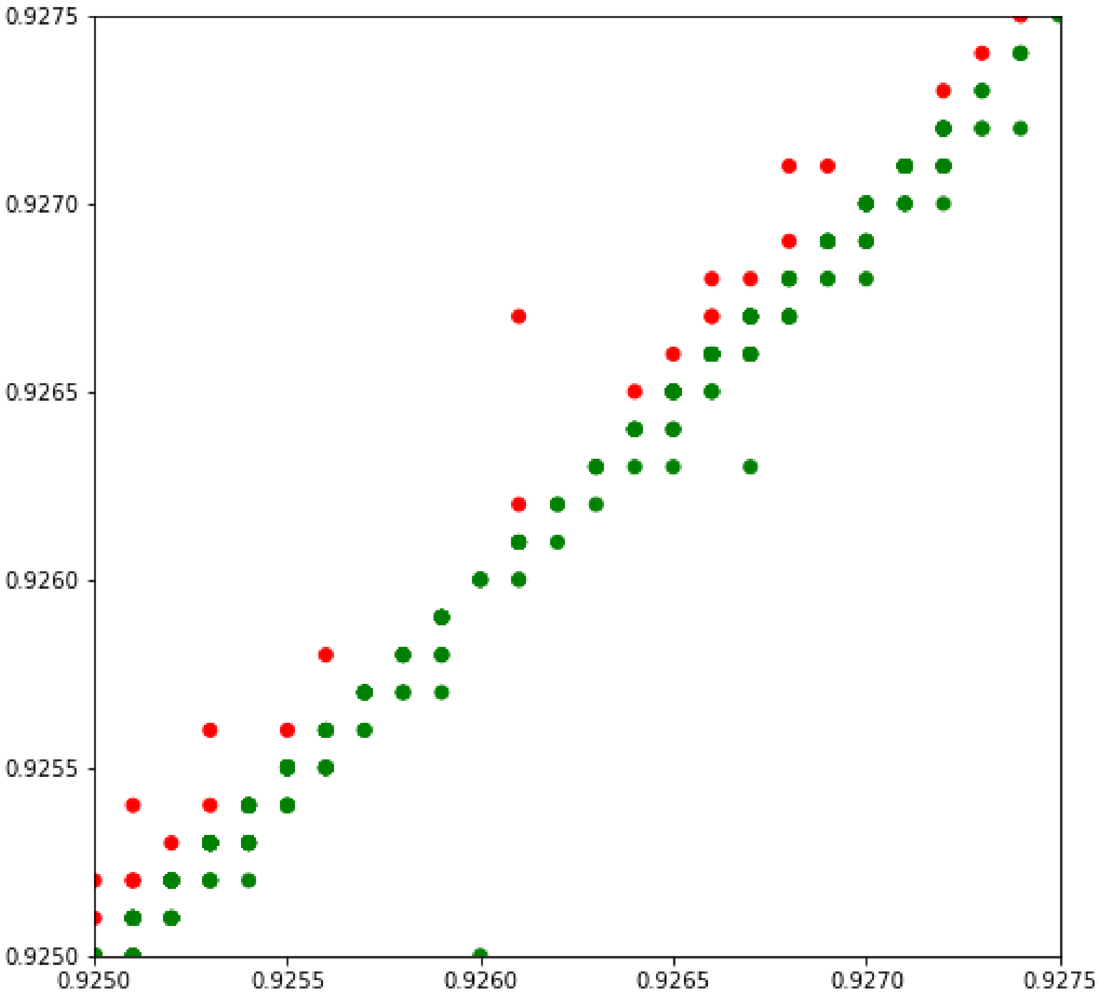
- Scatter plot between iou scores of two models.
- Green color signifies points where HRNet gave better iou score than UNet.
- Red color signifies points where UNet gave better iou score than HRNet.

[28]:
```
x = df['hrnet_iou_scores']
y = df['unet_iou_scores']
col = np.where(x<y,'red','green')
fig, ax = plt.subplots(figsize=(8,8))#
ax.scatter(x, y, c=col)
plt.xlim(0.92,0.94)
plt.ylim(0.92,0.94)
plt.show()
```



- Zooming the scatter plot we can see that there are more green points than red points.
- This signifies that HRNet has performed better than UNet.
- We can see points where UNet performed better is spread across the range.

```
[29]: x = df['hrnet_iou_scores']
      y = df['unet_iou_scores']
      col = np.where(x<y,'red','green')
      fig, ax = plt.subplots(figsize=(8,8))
      ax.scatter(x, y, c=col)
      plt.xlim(0.925,0.9275)
      plt.ylim(0.925,0.9275)
      plt.show()
```



- In this plot we can see that although HRNet has performed better than UNet but the difference is very small.