cs2_basicmodel

July 26, 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 tensorflow as tf
import cv2
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import seaborn as sns
from tqdm import tqdm

from tensorflow.keras import layers
from tensorflow.keras.layers import Input,Conv2D,MaxPool2D,Dropout,Concatenate,␣
↪Conv2DTranspose
from tensorflow.keras.models import Model
from tensorflow.keras.callbacks import EarlyStopping, ModelCheckpoint
import datetime
from PIL import Image, ImageStat
import math

%load_ext tensorboard
```

[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Warning: Looks like you're using an outdated API Version, please consider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_solution.csv.zip to /content
  0% 0.00/386k [00:00<?, ?B/s]
100% 386k/386k [00:00<00:00, 57.4MB/s]
Downloading stage1_test.zip to /content
  0% 0.00/9.10M [00:00<?, ?B/s]
100% 9.10M/9.10M [00:00<00:00, 83.7MB/s]
Downloading stage1_train.zip to /content
100% 79.0M/79.1M [00:00<00:00, 116MB/s]
100% 79.1M/79.1M [00:00<00:00, 156MB/s]
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, 88.7MB/s]
Downloading stage2_test_final.zip to /content
 95% 263M/276M [00:02<00:00, 131MB/s]
100% 276M/276M [00:02<00:00, 115MB/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, 33.9MB/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, 2.71MB/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 [00:30<00:00, 22.16it/s]
```

[14]:
```
train.head()
```

[14]:

	images	masks
0	./train/8b12e18670e4b24d03567d1e17c0c24fadf0ea2c1e763983dd6bb4c44b7376a6/images/8b12e18670e4b24d03567d1e17c0c24fadf0ea2c1e763983dd6bb4c44b7376a6.png	./train/8b12e18670e4b24d03567d1e17c0c24fadf0ea2c1e763983dd6bb4c44b7376a6/masks_/8b12e18670e4b24d03567d1e17c0c24fadf0ea2c1e763983dd6bb4c44b7376a6.png
1	./train/40bcdad218ac5f0885fc247d88fcad9f729f55c81c79d241a8f1559b6d8c0574/images/40bcdad218ac5f0885fc247d88fcad9f729f55c81c79d241a8f1559b6d8c0574.png	./train/40bcdad218ac5f0885fc247d88fcad9f729f55c81c79d241a8f1559b6d8c0574/masks_/40bcdad218ac5f0885fc247d88fcad9f729f55c81c79d241a8f1559b6d8c0574.png
2	./train/cc88627344305b9a9b07f8bd042cb074c7a834c13de67ff4b24914ac68f07f6e/images/cc88627344305b9a9b07f8bd042cb074c7a834c13de67ff4b24914ac68f07f6e.png	./train/cc88627344305b9a9b07f8bd042cb074c7a834c13de67ff4b24914ac68f07f6e/masks_/cc88627344305b9a9b07f8bd042cb074c7a834c13de67ff4b24914ac68f07f6e.png
3	./train/bc115ff727e997a88f7cfe4ce817745731a6c753cb9fab6a36e7e66b415a1d3d/images/bc115ff727e997a88f7cfe4ce817745731a6c753cb9fab6a36e7e66b415a1d3d.png	./train/bc115ff727e997a88f7cfe4ce817745731a6c753cb9fab6a36e7e66b415a1d3d/masks_/bc115ff727e997a88f7cfe4ce817745731a6c753cb9fab6a36e7e66b415a1d3d.png
4	./train/df53d0b6c2c4e45d759b2c474011e2b2b32552cd100ca4b22388ab9ca1750ee2/images/df53d0b6c2c4e45d759b2c474011e2b2b32552cd100ca4b22388ab9ca1750ee2.png	./train/df53d0b6c2c4e45d759b2c474011e2b2b32552cd100ca4b22388ab9ca1750ee2/masks_/df53d0b6c2c4e45d759b2c474011e2b2b32552cd100ca4b22388ab9ca1750ee2.png

3 Train Test Split

[15]:
```
X_train, X_val = train_test_split(train, test_size=0.1, random_state=42)
```

[16]:
```
X_train.head()
```

[16]:
```
                                                                images
masks
300  ./train/ac8169a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f/im
ages/ac8169a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f.png  ./tra
in/ac8169a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f/masks_/ac816
9a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f.png
60   ./train/b61d3fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895/im
ages/b61d3fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895.png  ./tra
in/b61d3fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895/masks_/b61d3
fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895.png
133  ./train/9fb32aba1c2fd53273dca9abefac944ba747f578da82dfaa1249f332a2324944/im
ages/9fb32aba1c2fd53273dca9abefac944ba747f578da82dfaa1249f332a2324944.png  ./tra
in/9fb32aba1c2fd53273dca9abefac944ba747f578da82dfaa1249f332a2324944/masks_/9fb32
aba1c2fd53273dca9abefac944ba747f578da82dfaa1249f332a2324944.png
30   ./train/220b37f4ca7cab486d2b71cd87a46ee7411a5aa142799d96ed98015ab5ba538a/im
ages/220b37f4ca7cab486d2b71cd87a46ee7411a5aa142799d96ed98015ab5ba538a.png  ./tra
in/220b37f4ca7cab486d2b71cd87a46ee7411a5aa142799d96ed98015ab5ba538a/masks_/220b3
7f4ca7cab486d2b71cd87a46ee7411a5aa142799d96ed98015ab5ba538a.png
69   ./train/4596961c789d3b41916492918797724fe75128239fefc516c3ee75322b7926f0/im
ages/4596961c789d3b41916492918797724fe75128239fefc516c3ee75322b7926f0.png  ./tra
in/4596961c789d3b41916492918797724fe75128239fefc516c3ee75322b7926f0/masks_/45969
61c789d3b41916492918797724fe75128239fefc516c3ee75322b7926f0.png
```

[17]:
```
X_val.head()
```

[17]:
```
                                                                images
masks
361  ./train/f8e74d4006dd68c1dbe68df7be905835e00d8ba4916f3b18884509a15fdc0b55/im
ages/f8e74d4006dd68c1dbe68df7be905835e00d8ba4916f3b18884509a15fdc0b55.png  ./tra
in/f8e74d4006dd68c1dbe68df7be905835e00d8ba4916f3b18884509a15fdc0b55/masks_/f8e74
d4006dd68c1dbe68df7be905835e00d8ba4916f3b18884509a15fdc0b55.png
158  ./train/5d2c98fd6fda3c7d739461c3b3d4a0c7f8456121a14519dc5955a1775227b053/im
ages/5d2c98fd6fda3c7d739461c3b3d4a0c7f8456121a14519dc5955a1775227b053.png  ./tra
in/5d2c98fd6fda3c7d739461c3b3d4a0c7f8456121a14519dc5955a1775227b053/masks_/5d2c9
8fd6fda3c7d739461c3b3d4a0c7f8456121a14519dc5955a1775227b053.png
480  ./train/f01a9742c43a69f087700a43893f713878e537bae8e44f76b957f09519601ad6/im
ages/f01a9742c43a69f087700a43893f713878e537bae8e44f76b957f09519601ad6.png  ./tra
in/f01a9742c43a69f087700a43893f713878e537bae8e44f76b957f09519601ad6/masks_/f01a9
742c43a69f087700a43893f713878e537bae8e44f76b957f09519601ad6.png
640  ./train/9620c33d8ef2772dbc5bd152429f507bd7fafb27e12109003292b671e556b089/im
ages/9620c33d8ef2772dbc5bd152429f507bd7fafb27e12109003292b671e556b089.png  ./tra
```

```
in/9620c33d8ef2772dbc5bd152429f507bd7fafb27e12109003292b671e556b089/masks_/9620c
33d8ef2772dbc5bd152429f507bd7fafb27e12109003292b671e556b089.png
275  ./train/237802ac5005f9cf782367156c46c383efd9e05088e5768ca883cbbe24abadb1/im
ages/237802ac5005f9cf782367156c46c383efd9e05088e5768ca883cbbe24abadb1.png  ./tra
in/237802ac5005f9cf782367156c46c383efd9e05088e5768ca883cbbe24abadb1/masks_/23780
2ac5005f9cf782367156c46c383efd9e05088e5768ca883cbbe24abadb1.png
```

4 Data Preprocessing

[18]:
```python
# Function to parse image and mask file path and convert them into image and␣
↪mask
def parse_function(image_path, mask_path):
    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])
    return image, mask
```

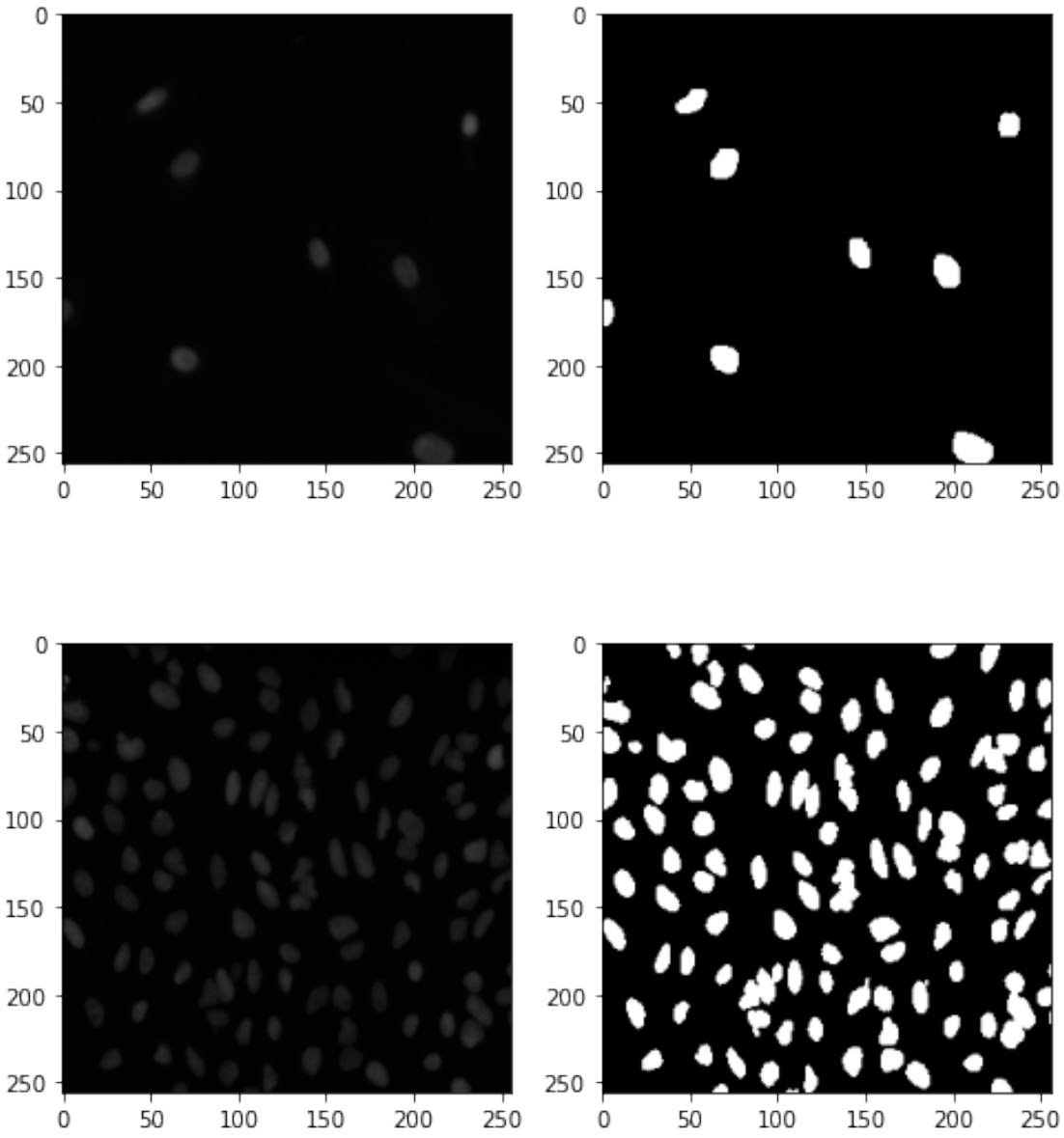
[19]:
```python
# Training dataset
train_ds = tf.data.Dataset.from_tensor_slices((X_train['images'],␣
↪X_train['masks']))
train_ds = train_ds.shuffle(X_train.shape[0])
train_ds = train_ds.map(parse_function, num_parallel_calls=tf.data.AUTOTUNE)
train_ds = train_ds.batch(BATCH_SIZE)
train_ds = train_ds.prefetch(1)
```

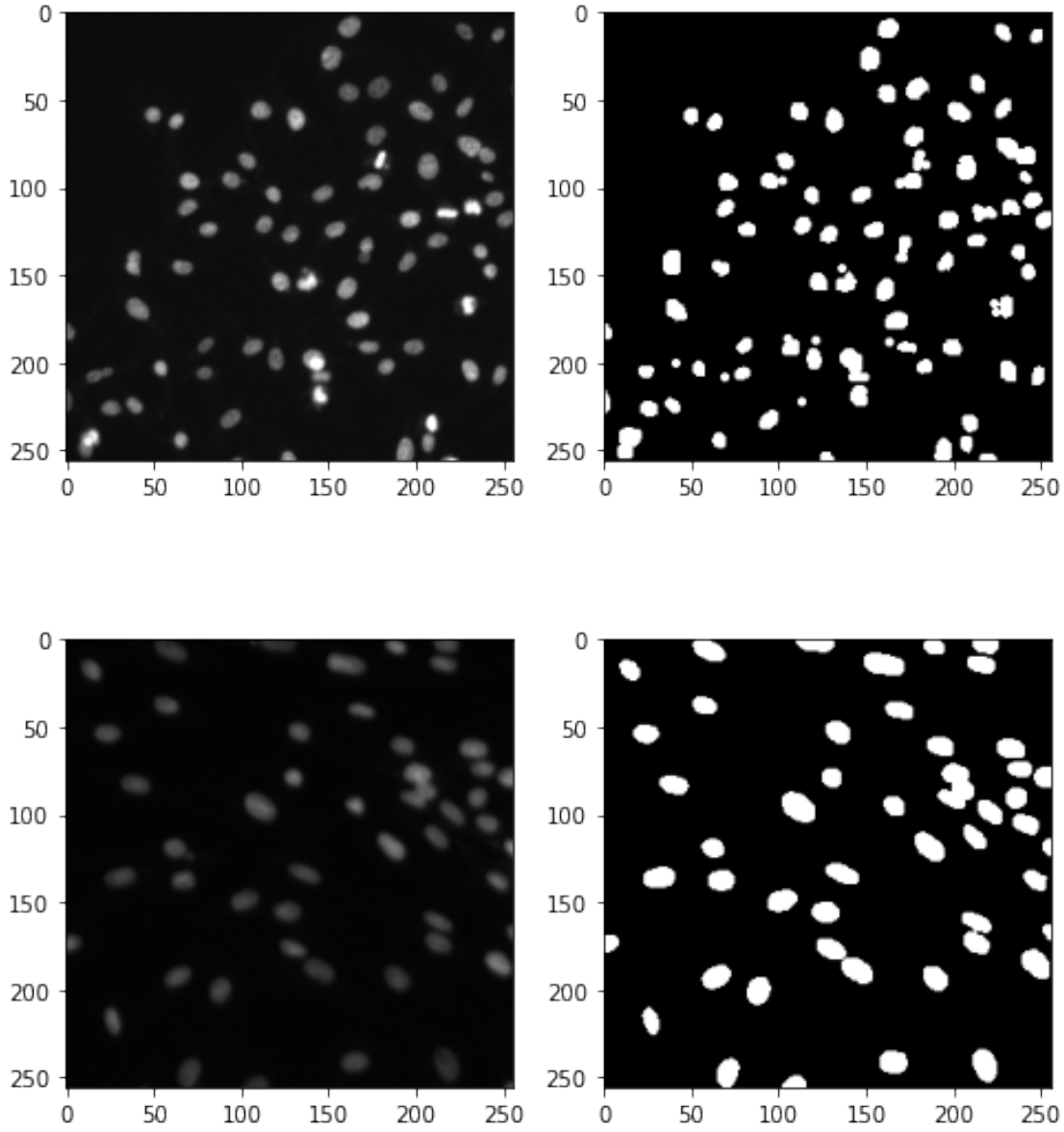
[20]:
```python
# Validation dataset
val_ds = tf.data.Dataset.from_tensor_slices((X_val['images'], X_val['masks']))
val_ds = val_ds.map(parse_function, num_parallel_calls=tf.data.AUTOTUNE)
val_ds = val_ds.batch(BATCH_SIZE)
val_ds = val_ds.prefetch(1)
```

5 Sample of Train and Validation datasets

[22]:
```python
# Sample of training dataset
for image, mask in train_ds.take(1):
    for i in range(BATCH_SIZE):
        plt.figure(figsize=(8,4))
        plt.subplot(121)
        plt.imshow(image[i])
```

```
        plt.subplot(122)
        plt.imshow(mask[i][:,:,0], cmap = 'gray')
        plt.show()
```

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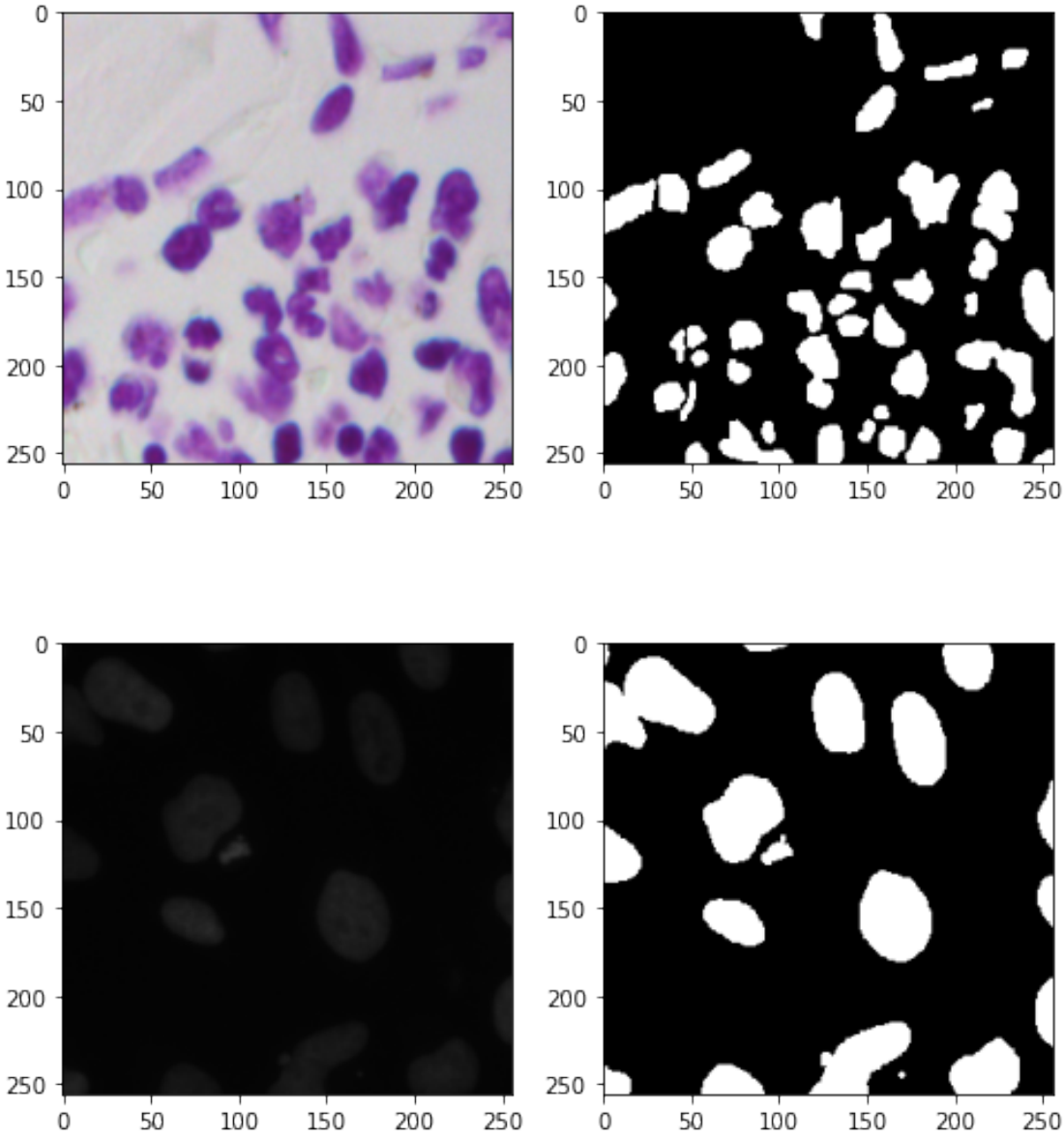
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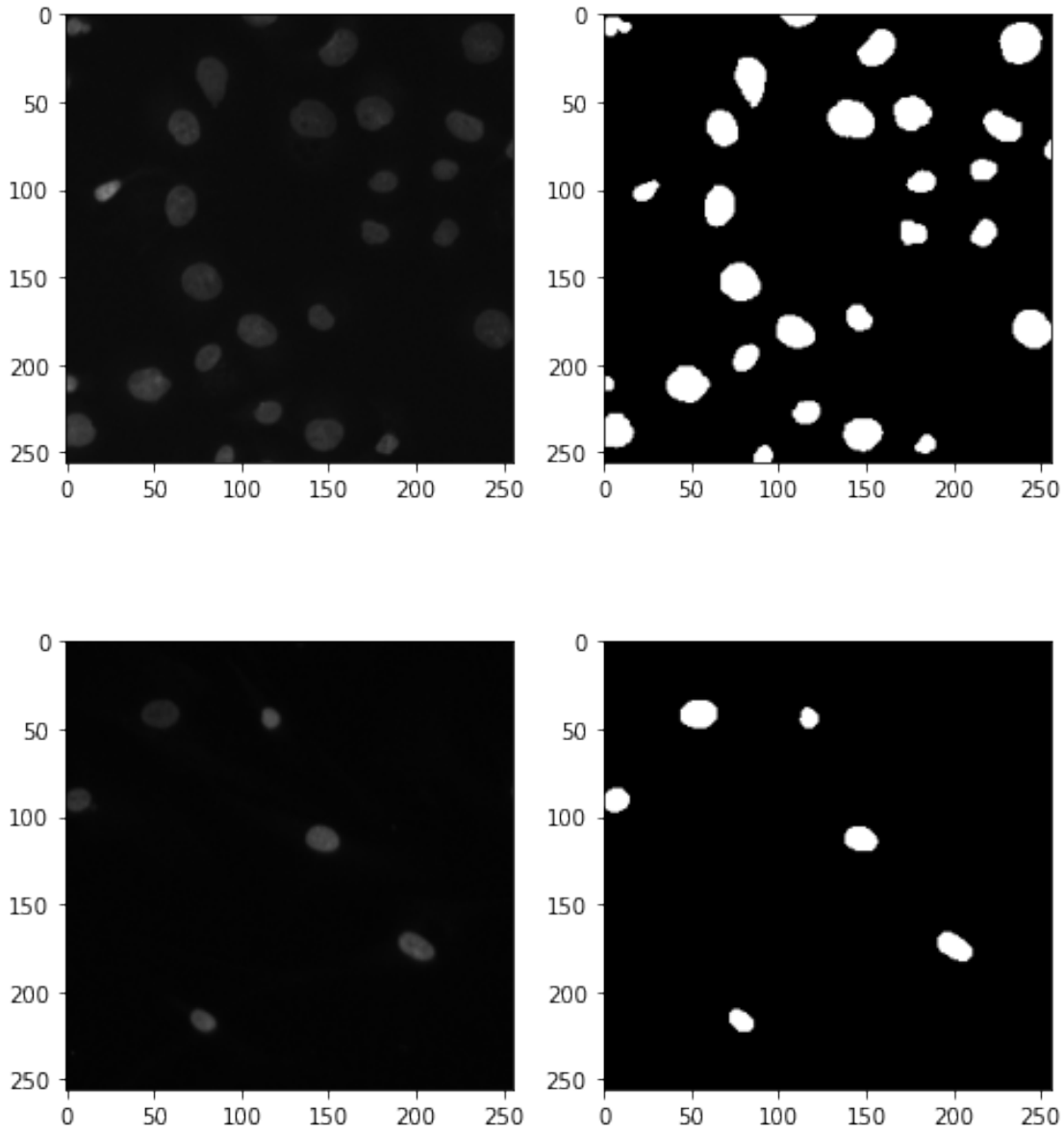
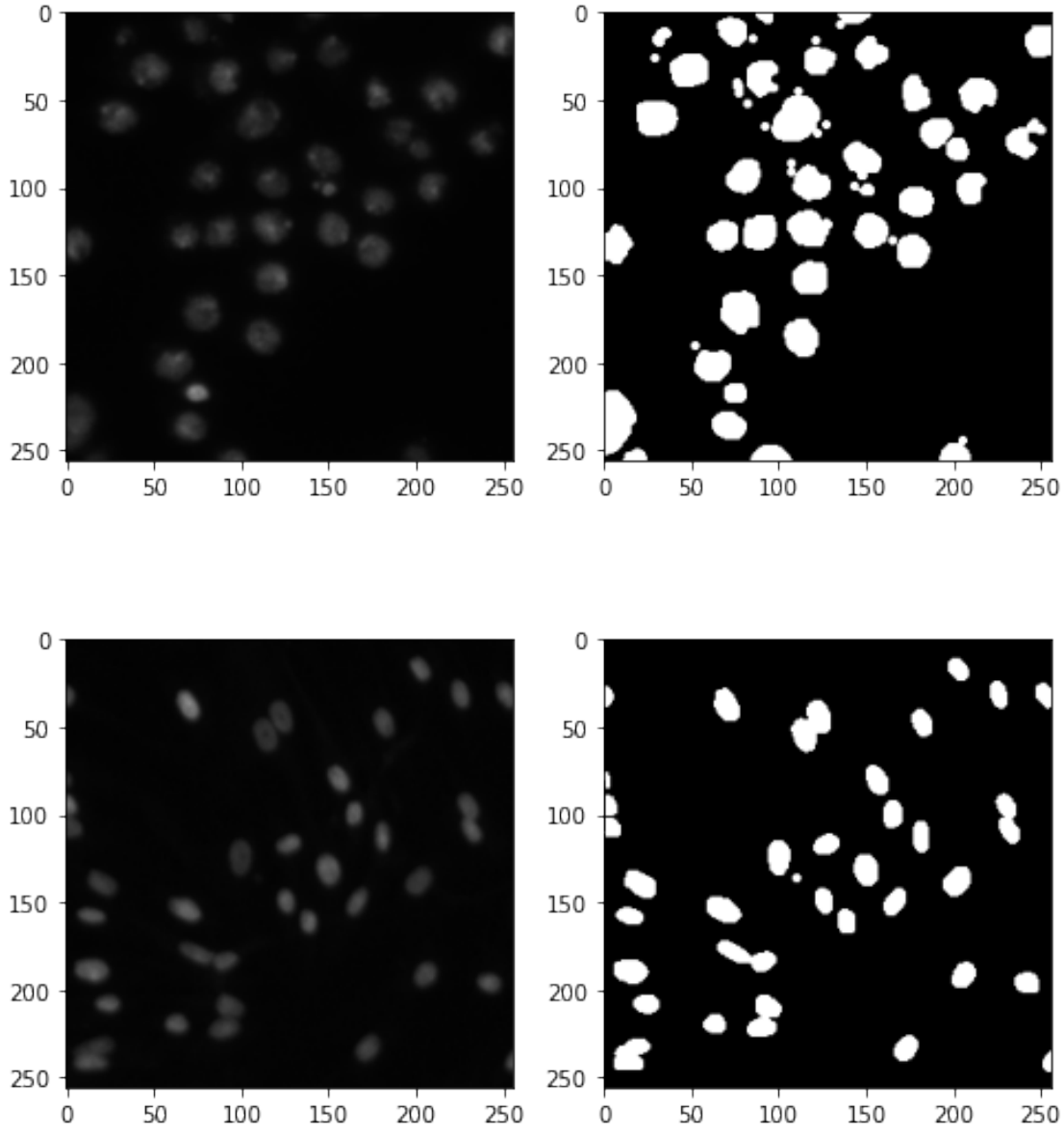


[23]:
```
# Sample of validation dataset
for image, mask in val_ds.take(1):
    for i in range(BATCH_SIZE):
        plt.figure(figsize=(8,4))
        plt.subplot(121)
        plt.imshow(image[i])
        plt.subplot(122)
        plt.imshow(mask[i][:,:,0], cmap = 'gray')
        plt.show()
```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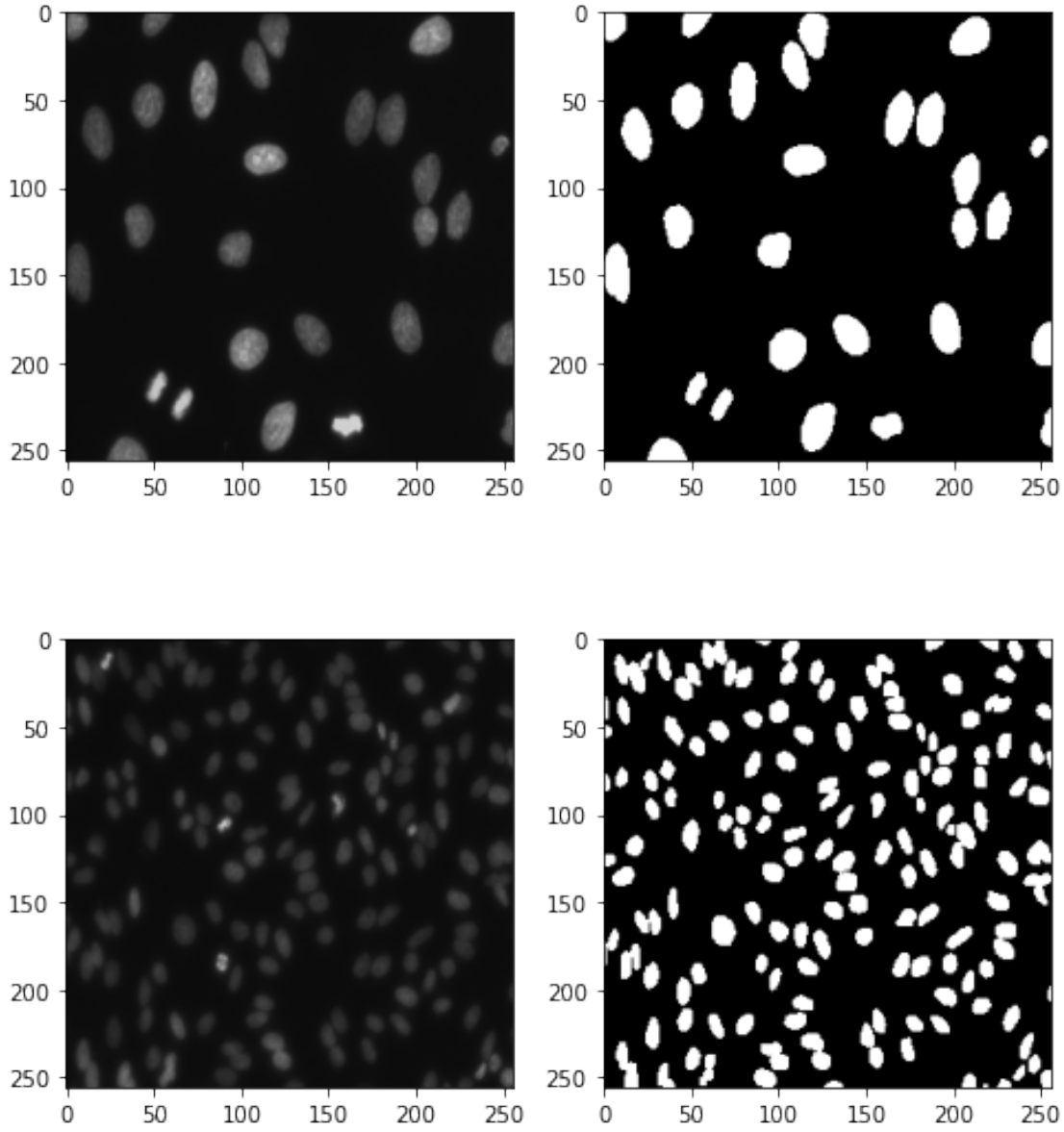
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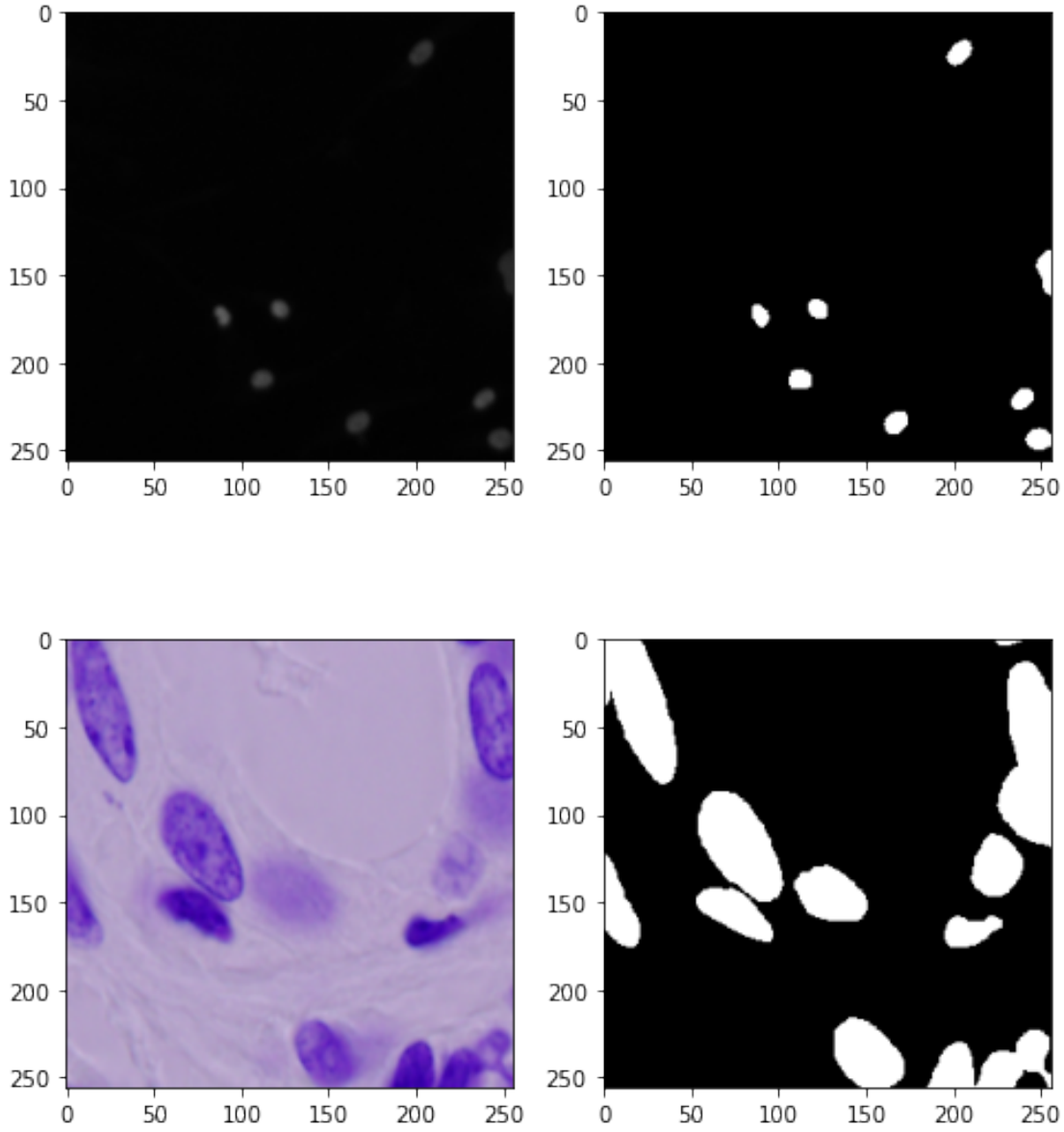
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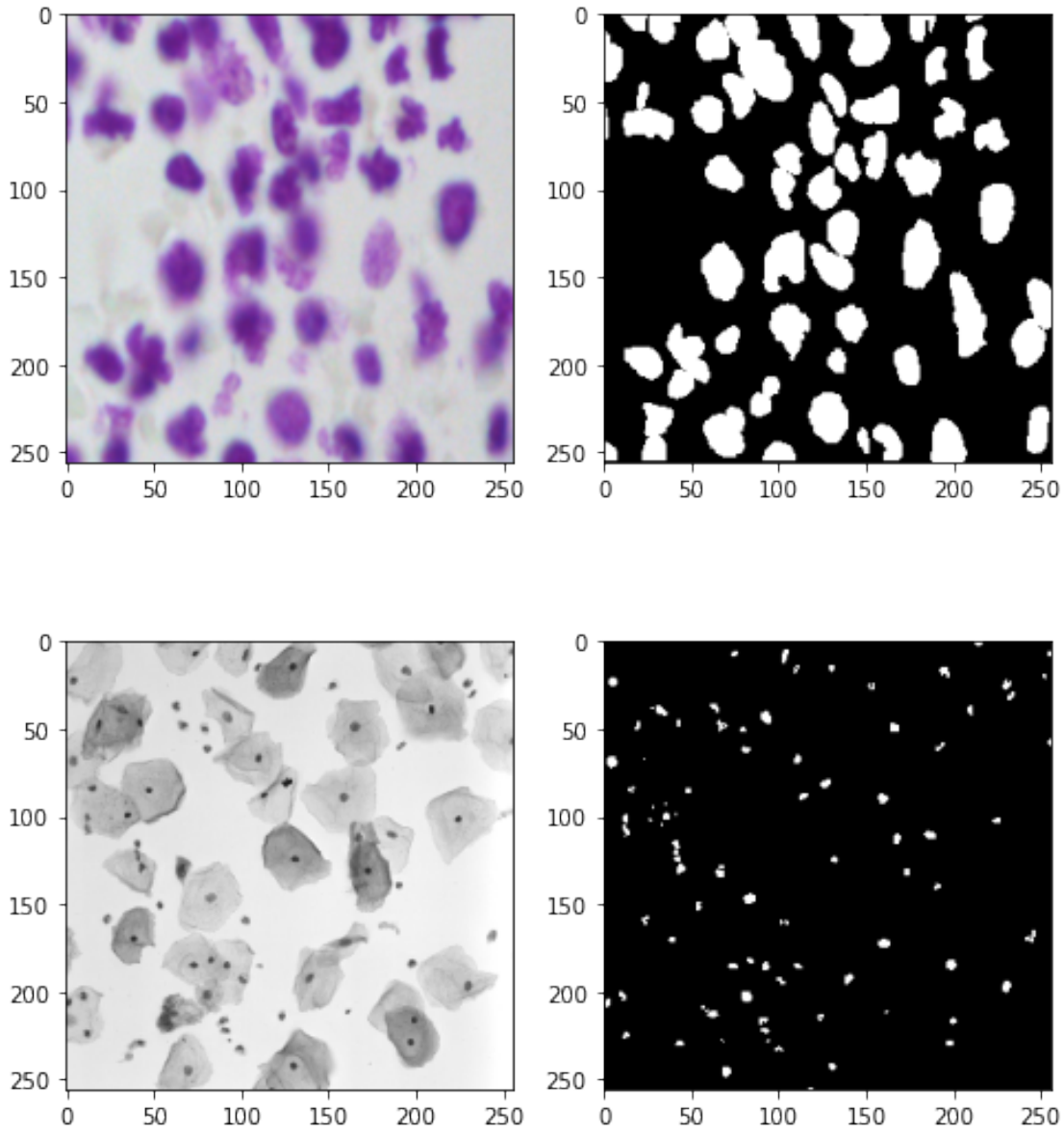


6 Basic Model - Unet

6.1 Performance Metric

[24]:
```
# 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()))
```

6.2 Architecture

[25]:
```
mean_iou = MeanIoU(2, 0.4)
```

[26]:
```
# Input Layer
# Input shape 256X256X3
inputs = Input((IMG_HEIGHT, IMG_WIDTH, IMG_CHANNELS))

# Left Side/Downsampling Side
# 256 -> 128
conv1 = Conv2D(16, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(inputs)
conv1 = Conv2D(16, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(conv1)
pool1 = MaxPool2D((2, 2))(conv1)
pool1 = Dropout(0.25)(pool1)

# 128 -> 64
conv2 = Conv2D(32, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(pool1)
conv2 = Conv2D(32, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(conv2)
pool2 = MaxPool2D((2, 2))(conv2)
pool2 = Dropout(0.5)(pool2)

# 64 -> 32
conv3 = Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(pool2)
conv3 = Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(conv3)
pool3 = MaxPool2D((2, 2))(conv3)
pool3 = Dropout(0.5)(pool3)

# 32 -> 16
conv4 = Conv2D(128, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(pool3)
conv4 = Conv2D(128, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(conv4)
pool4 = MaxPool2D((2, 2))(conv4)
pool4 = Dropout(0.5)(pool4)

# Middle Part
```

```
# 16 -> 16
convm = Conv2D(256, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(pool4)
convm = Conv2D(256, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(convm)

# Right Side/ Upsampling Side
# 16 -> 32
uconv4 = Conv2DTranspose(128, (2, 2), strides=(2, 2), padding='same')(convm)
uconv4 = Concatenate()([uconv4, conv4])
uconv4 = Dropout(0.5)(uconv4)
uconv4 = Conv2D(128, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv4)
uconv4 = Conv2D(128, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv4)

# 32 -> 64
uconv3 = Conv2DTranspose(64, (2, 2), strides=(2, 2), padding='same')(uconv4)
uconv3 = Concatenate()([uconv3, conv3])
uconv3 = Dropout(0.5)(uconv3)
uconv3 = Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv3)
uconv3 = Conv2D(64, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv3)

# 64 -> 128
uconv2 = Conv2DTranspose(32, (2, 2), strides=(2, 2), padding='same')(uconv3)
uconv2 = Concatenate()([uconv2, conv2])
uconv2 = Dropout(0.5)(uconv2)
uconv2 = Conv2D(32, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv2)
uconv2 = Conv2D(32, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv2)

# 128 -> 256
uconv1 = Conv2DTranspose(16, (2, 2), strides=(2, 2), padding='same')(uconv2)
uconv1 = Concatenate()([uconv1, conv1])
uconv1 = Dropout(0.5)(uconv1)
uconv1 = Conv2D(16, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv1)
uconv1 = Conv2D(16, (3, 3), activation='relu', kernel_initializer='he_normal',␣
 ↪padding='same')(uconv1)

# Output Layer
# Output shape 256X256X1
outputs = Conv2D(CLASSES, (1, 1), activation='sigmoid')(uconv1)
```

```
model = Model(inputs=[inputs], outputs=[outputs])
model.compile(optimizer='adam', loss='binary_crossentropy', metrics=[mean_iou])#
model.summary()
```

```
Model: "model"
_________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
=================================================================================
==================
input_1 (InputLayer)            [(None, 256, 256, 3) 0
_________________________________________________________________________________
__________________
conv2d (Conv2D)                 (None, 256, 256, 16) 448         input_1[0][0]
_________________________________________________________________________________
__________________
conv2d_1 (Conv2D)               (None, 256, 256, 16) 2320        conv2d[0][0]
_________________________________________________________________________________
__________________
max_pooling2d (MaxPooling2D)    (None, 128, 128, 16) 0           conv2d_1[0][0]
_________________________________________________________________________________
__________________
dropout (Dropout)               (None, 128, 128, 16) 0
max_pooling2d[0][0]
_________________________________________________________________________________
__________________
conv2d_2 (Conv2D)               (None, 128, 128, 32) 4640        dropout[0][0]
_________________________________________________________________________________
__________________
conv2d_3 (Conv2D)               (None, 128, 128, 32) 9248        conv2d_2[0][0]
_________________________________________________________________________________
__________________
max_pooling2d_1 (MaxPooling2D)  (None, 64, 64, 32)   0           conv2d_3[0][0]
_________________________________________________________________________________
__________________
dropout_1 (Dropout)             (None, 64, 64, 32)   0
max_pooling2d_1[0][0]
_________________________________________________________________________________
__________________
conv2d_4 (Conv2D)               (None, 64, 64, 64)   18496       dropout_1[0][0]
_________________________________________________________________________________
__________________
conv2d_5 (Conv2D)               (None, 64, 64, 64)   36928       conv2d_4[0][0]
_________________________________________________________________________________
__________________
max_pooling2d_2 (MaxPooling2D)  (None, 32, 32, 64)   0           conv2d_5[0][0]
```

```
____________________________________________________________________________
__________________
dropout_2 (Dropout)             (None, 32, 32, 64)   0
max_pooling2d_2[0][0]
____________________________________________________________________________
__________________
conv2d_6 (Conv2D)               (None, 32, 32, 128)  73856       dropout_2[0][0]
____________________________________________________________________________
__________________
conv2d_7 (Conv2D)               (None, 32, 32, 128)  147584      conv2d_6[0][0]
____________________________________________________________________________
__________________
max_pooling2d_3 (MaxPooling2D)  (None, 16, 16, 128)  0           conv2d_7[0][0]
____________________________________________________________________________
__________________
dropout_3 (Dropout)             (None, 16, 16, 128)  0
max_pooling2d_3[0][0]
____________________________________________________________________________
__________________
conv2d_8 (Conv2D)               (None, 16, 16, 256)  295168      dropout_3[0][0]
____________________________________________________________________________
__________________
conv2d_9 (Conv2D)               (None, 16, 16, 256)  590080      conv2d_8[0][0]
____________________________________________________________________________
__________________
conv2d_transpose (Conv2DTranspo (None, 32, 32, 128)  131200      conv2d_9[0][0]
____________________________________________________________________________
__________________
concatenate (Concatenate)       (None, 32, 32, 256)  0
conv2d_transpose[0][0]
                                                                 conv2d_7[0][0]
____________________________________________________________________________
__________________
dropout_4 (Dropout)             (None, 32, 32, 256)  0
concatenate[0][0]
____________________________________________________________________________
__________________
conv2d_10 (Conv2D)              (None, 32, 32, 128)  295040      dropout_4[0][0]
____________________________________________________________________________
__________________
conv2d_11 (Conv2D)              (None, 32, 32, 128)  147584      conv2d_10[0][0]
____________________________________________________________________________
__________________
conv2d_transpose_1 (Conv2DTrans (None, 64, 64, 64)   32832       conv2d_11[0][0]
____________________________________________________________________________
__________________
concatenate_1 (Concatenate)     (None, 64, 64, 128)  0
conv2d_transpose_1[0][0]
```

```
                                                                    conv2d_5[0][0]
__________________________________________________________________________________________________
dropout_5 (Dropout)             (None, 64, 64, 128)  0
concatenate_1[0][0]
__________________________________________________________________________________________________
conv2d_12 (Conv2D)              (None, 64, 64, 64)   73792       dropout_5[0][0]
__________________________________________________________________________________________________
conv2d_13 (Conv2D)              (None, 64, 64, 64)   36928       conv2d_12[0][0]
__________________________________________________________________________________________________
conv2d_transpose_2 (Conv2DTrans (None, 128, 128, 32) 8224        conv2d_13[0][0]
__________________________________________________________________________________________________
concatenate_2 (Concatenate)     (None, 128, 128, 64) 0
conv2d_transpose_2[0][0]
                                                                    conv2d_3[0][0]
__________________________________________________________________________________________________
dropout_6 (Dropout)             (None, 128, 128, 64) 0
concatenate_2[0][0]
__________________________________________________________________________________________________
conv2d_14 (Conv2D)              (None, 128, 128, 32) 18464       dropout_6[0][0]
__________________________________________________________________________________________________
conv2d_15 (Conv2D)              (None, 128, 128, 32) 9248        conv2d_14[0][0]
__________________________________________________________________________________________________
conv2d_transpose_3 (Conv2DTrans (None, 256, 256, 16) 2064        conv2d_15[0][0]
__________________________________________________________________________________________________
concatenate_3 (Concatenate)     (None, 256, 256, 32) 0
conv2d_transpose_3[0][0]
                                                                    conv2d_1[0][0]
__________________________________________________________________________________________________
dropout_7 (Dropout)             (None, 256, 256, 32) 0
concatenate_3[0][0]
__________________________________________________________________________________________________
conv2d_16 (Conv2D)              (None, 256, 256, 16) 4624        dropout_7[0][0]
__________________________________________________________________________________________________
conv2d_17 (Conv2D)              (None, 256, 256, 16) 2320        conv2d_16[0][0]
__________________________________________________________________________________________________
```

```
------------------
conv2d_18 (Conv2D)              (None, 256, 256, 1)  17          conv2d_17[0][0]
==================================================================================
==================
Total params: 1,941,105
Trainable params: 1,941,105
Non-trainable params: 0
----------------------------------------------------------------------------------
------------------
```

6.3 Callbacks

[27]:
```
!rm -rf ./model_save/
```

[28]:
```
# Modelcheckpoint callback
if not os.path.exists('model_save'):
    os.makedirs('model_save')
filepath="model_save/weights-{epoch:04d}.hdf5"
checkpoint = tf.keras.callbacks.ModelCheckpoint(filepath=filepath,
                                        save_best_only=True,
                                        mode='auto',
                                        monitor='val_loss')
```

[29]:
```
!rm -rf ./model/
```

[30]:
```
# Tensorboard Callback
log_dir = os.path.join("model", datetime.datetime.now().
 ↪strftime("%Y%m%d-%H%M%S"))
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=log_dir,
                                                      histogram_freq=1,
                                                      write_graph=True)
```

6.4 Training

[31]:
```
callbacks_list = [checkpoint, tensorboard_callback]
history = model.fit(train_ds,
                    initial_epoch = 0,
                    epochs=30,
                    callbacks=callbacks_list,
                    validation_data=val_ds)
```

```
Epoch 1/30
76/76 [==============================] - 45s 137ms/step - loss: 0.3766 -
mean_iou: 0.4305 - val_loss: 0.2563 - val_mean_iou: 0.5399
Epoch 2/30
76/76 [==============================] - 8s 98ms/step - loss: 0.1712 - mean_iou:
0.7676 - val_loss: 0.1942 - val_mean_iou: 0.7713
```

```
Epoch 3/30
76/76 [==============================] - 8s 98ms/step - loss: 0.1095 - mean_iou:
0.8448 - val_loss: 0.1644 - val_mean_iou: 0.7984
Epoch 4/30
76/76 [==============================] - 8s 100ms/step - loss: 0.1012 -
mean_iou: 0.8538 - val_loss: 0.1279 - val_mean_iou: 0.8246
Epoch 5/30
76/76 [==============================] - 8s 100ms/step - loss: 0.0909 -
mean_iou: 0.8651 - val_loss: 0.1218 - val_mean_iou: 0.8280
Epoch 6/30
76/76 [==============================] - 8s 100ms/step - loss: 0.0839 -
mean_iou: 0.8738 - val_loss: 0.1145 - val_mean_iou: 0.8325
Epoch 7/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0813 -
mean_iou: 0.8792 - val_loss: 0.1105 - val_mean_iou: 0.8383
Epoch 8/30
76/76 [==============================] - 8s 103ms/step - loss: 0.0767 -
mean_iou: 0.8822 - val_loss: 0.1007 - val_mean_iou: 0.8422
Epoch 9/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0771 -
mean_iou: 0.8835 - val_loss: 0.1014 - val_mean_iou: 0.8430
Epoch 10/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0759 -
mean_iou: 0.8825 - val_loss: 0.0981 - val_mean_iou: 0.8469
Epoch 11/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0743 -
mean_iou: 0.8854 - val_loss: 0.0970 - val_mean_iou: 0.8460
Epoch 12/30
76/76 [==============================] - 8s 99ms/step - loss: 0.0730 - mean_iou:
0.8867 - val_loss: 0.0903 - val_mean_iou: 0.8618
Epoch 13/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0723 -
mean_iou: 0.8877 - val_loss: 0.0955 - val_mean_iou: 0.8574
Epoch 14/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0746 -
mean_iou: 0.8861 - val_loss: 0.0882 - val_mean_iou: 0.8708
Epoch 15/30
76/76 [==============================] - 8s 100ms/step - loss: 0.0798 -
mean_iou: 0.8813 - val_loss: 0.0923 - val_mean_iou: 0.8589
Epoch 16/30
76/76 [==============================] - 8s 104ms/step - loss: 0.0731 -
mean_iou: 0.8873 - val_loss: 0.0892 - val_mean_iou: 0.8778
Epoch 17/30
76/76 [==============================] - 8s 104ms/step - loss: 0.0719 -
mean_iou: 0.8891 - val_loss: 0.0947 - val_mean_iou: 0.8680
Epoch 18/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0711 -
mean_iou: 0.8892 - val_loss: 0.0879 - val_mean_iou: 0.8729
```

```
Epoch 19/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0703 -
mean_iou: 0.8892 - val_loss: 0.0846 - val_mean_iou: 0.8853
Epoch 20/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0681 -
mean_iou: 0.8930 - val_loss: 0.0797 - val_mean_iou: 0.8870
Epoch 21/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0673 -
mean_iou: 0.8944 - val_loss: 0.0792 - val_mean_iou: 0.8954
Epoch 22/30
76/76 [==============================] - 8s 103ms/step - loss: 0.0693 -
mean_iou: 0.8919 - val_loss: 0.0785 - val_mean_iou: 0.8946
Epoch 23/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0700 -
mean_iou: 0.8913 - val_loss: 0.0763 - val_mean_iou: 0.8936
Epoch 24/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0701 -
mean_iou: 0.8916 - val_loss: 0.0756 - val_mean_iou: 0.8962
Epoch 25/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0673 -
mean_iou: 0.8946 - val_loss: 0.0745 - val_mean_iou: 0.8967
Epoch 26/30
76/76 [==============================] - 8s 105ms/step - loss: 0.0658 -
mean_iou: 0.8963 - val_loss: 0.0717 - val_mean_iou: 0.8996
Epoch 27/30
76/76 [==============================] - 8s 104ms/step - loss: 0.0658 -
mean_iou: 0.8963 - val_loss: 0.0891 - val_mean_iou: 0.8745
Epoch 28/30
76/76 [==============================] - 8s 101ms/step - loss: 0.0677 -
mean_iou: 0.8952 - val_loss: 0.0765 - val_mean_iou: 0.8950
Epoch 29/30
76/76 [==============================] - 8s 103ms/step - loss: 0.0646 -
mean_iou: 0.8985 - val_loss: 0.0757 - val_mean_iou: 0.8903
Epoch 30/30
76/76 [==============================] - 8s 102ms/step - loss: 0.0645 -
mean_iou: 0.8980 - val_loss: 0.0758 - val_mean_iou: 0.8898
```

[32]:
```
initial_epoch = int(sorted(os.listdir('model_save'))[-1].split('.')[0].
 ↪split('-')[-1])
history = model.fit(train_ds,
                    initial_epoch = initial_epoch,
                    epochs=60,
                    callbacks=callbacks_list,
                    validation_data=val_ds)
```

```
Epoch 27/60
76/76 [==============================] - 9s 113ms/step - loss: 0.0645 -
mean_iou: 0.8981 - val_loss: 0.0739 - val_mean_iou: 0.8980
```

```
Epoch 28/60
76/76 [==============================] - 8s 103ms/step - loss: 0.0635 -
mean_iou: 0.8992 - val_loss: 0.0714 - val_mean_iou: 0.8986
Epoch 29/60
76/76 [==============================] - 8s 102ms/step - loss: 0.0649 -
mean_iou: 0.8973 - val_loss: 0.0962 - val_mean_iou: 0.8600
Epoch 30/60
76/76 [==============================] - 8s 108ms/step - loss: 0.0659 -
mean_iou: 0.8955 - val_loss: 0.0762 - val_mean_iou: 0.8937
Epoch 31/60
76/76 [==============================] - 9s 119ms/step - loss: 0.0647 -
mean_iou: 0.8977 - val_loss: 0.0812 - val_mean_iou: 0.8880
Epoch 32/60
76/76 [==============================] - 9s 117ms/step - loss: 0.0636 -
mean_iou: 0.8993 - val_loss: 0.0741 - val_mean_iou: 0.8937
Epoch 33/60
76/76 [==============================] - 9s 114ms/step - loss: 0.0623 -
mean_iou: 0.9008 - val_loss: 0.0813 - val_mean_iou: 0.8900
Epoch 34/60
76/76 [==============================] - 9s 122ms/step - loss: 0.0661 -
mean_iou: 0.8955 - val_loss: 0.0710 - val_mean_iou: 0.8974
Epoch 35/60
76/76 [==============================] - 9s 121ms/step - loss: 0.0641 -
mean_iou: 0.8986 - val_loss: 0.0753 - val_mean_iou: 0.8902
Epoch 36/60
76/76 [==============================] - 8s 107ms/step - loss: 0.0650 -
mean_iou: 0.8980 - val_loss: 0.0692 - val_mean_iou: 0.9003
Epoch 37/60
76/76 [==============================] - 8s 107ms/step - loss: 0.0607 -
mean_iou: 0.9026 - val_loss: 0.0729 - val_mean_iou: 0.9004
Epoch 38/60
76/76 [==============================] - 8s 105ms/step - loss: 0.0629 -
mean_iou: 0.8991 - val_loss: 0.0689 - val_mean_iou: 0.9031
Epoch 39/60
76/76 [==============================] - 8s 105ms/step - loss: 0.0611 -
mean_iou: 0.9024 - val_loss: 0.0717 - val_mean_iou: 0.8976
Epoch 40/60
76/76 [==============================] - 8s 102ms/step - loss: 0.0604 -
mean_iou: 0.9034 - val_loss: 0.0705 - val_mean_iou: 0.8953
Epoch 41/60
76/76 [==============================] - 9s 120ms/step - loss: 0.0613 -
mean_iou: 0.9013 - val_loss: 0.0694 - val_mean_iou: 0.9024
Epoch 42/60
76/76 [==============================] - 10s 130ms/step - loss: 0.0604 -
mean_iou: 0.9030 - val_loss: 0.0685 - val_mean_iou: 0.9014
Epoch 43/60
76/76 [==============================] - 10s 127ms/step - loss: 0.0613 -
mean_iou: 0.9016 - val_loss: 0.0862 - val_mean_iou: 0.8917
```

```
Epoch 44/60
76/76 [==============================] - 10s 126ms/step - loss: 0.0599 -
mean_iou: 0.9043 - val_loss: 0.0681 - val_mean_iou: 0.9031
Epoch 45/60
76/76 [==============================] - 10s 124ms/step - loss: 0.0609 -
mean_iou: 0.9027 - val_loss: 0.0676 - val_mean_iou: 0.9021
Epoch 46/60
76/76 [==============================] - 9s 122ms/step - loss: 0.0612 -
mean_iou: 0.9022 - val_loss: 0.0773 - val_mean_iou: 0.8895
Epoch 47/60
76/76 [==============================] - 9s 121ms/step - loss: 0.0609 -
mean_iou: 0.9019 - val_loss: 0.0739 - val_mean_iou: 0.8949
Epoch 48/60
76/76 [==============================] - 9s 112ms/step - loss: 0.0701 -
mean_iou: 0.8918 - val_loss: 0.0692 - val_mean_iou: 0.9027
Epoch 49/60
76/76 [==============================] - 8s 108ms/step - loss: 0.0625 -
mean_iou: 0.9016 - val_loss: 0.0698 - val_mean_iou: 0.9001
Epoch 50/60
76/76 [==============================] - 8s 108ms/step - loss: 0.0602 -
mean_iou: 0.9044 - val_loss: 0.0765 - val_mean_iou: 0.8992
Epoch 51/60
76/76 [==============================] - 8s 103ms/step - loss: 0.0602 -
mean_iou: 0.9038 - val_loss: 0.0767 - val_mean_iou: 0.8909
Epoch 52/60
76/76 [==============================] - 8s 102ms/step - loss: 0.0590 -
mean_iou: 0.9050 - val_loss: 0.0670 - val_mean_iou: 0.9042
Epoch 53/60
76/76 [==============================] - 8s 101ms/step - loss: 0.0580 -
mean_iou: 0.9063 - val_loss: 0.0675 - val_mean_iou: 0.9032
Epoch 54/60
76/76 [==============================] - 8s 101ms/step - loss: 0.0572 -
mean_iou: 0.9074 - val_loss: 0.0684 - val_mean_iou: 0.9004
Epoch 55/60
76/76 [==============================] - 8s 104ms/step - loss: 0.0586 -
mean_iou: 0.9053 - val_loss: 0.0951 - val_mean_iou: 0.8530
Epoch 56/60
76/76 [==============================] - 8s 101ms/step - loss: 0.0631 -
mean_iou: 0.8977 - val_loss: 0.0694 - val_mean_iou: 0.9011
Epoch 57/60
76/76 [==============================] - 8s 100ms/step - loss: 0.0586 -
mean_iou: 0.9060 - val_loss: 0.0705 - val_mean_iou: 0.8980
Epoch 58/60
76/76 [==============================] - 8s 103ms/step - loss: 0.0583 -
mean_iou: 0.9054 - val_loss: 0.0670 - val_mean_iou: 0.9030
Epoch 59/60
76/76 [==============================] - 8s 104ms/step - loss: 0.0578 -
mean_iou: 0.9071 - val_loss: 0.0716 - val_mean_iou: 0.8953
```

```
Epoch 60/60
76/76 [==============================] - 8s 104ms/step - loss: 0.0573 -
mean_iou: 0.9073 - val_loss: 0.0667 - val_mean_iou: 0.9064
```

6.5 Tensorboard

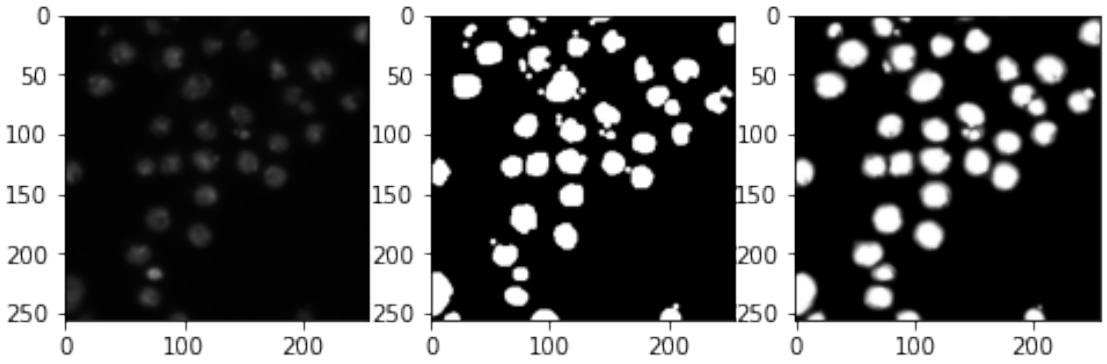
[33]:
```
%tensorboard --logdir model1
```

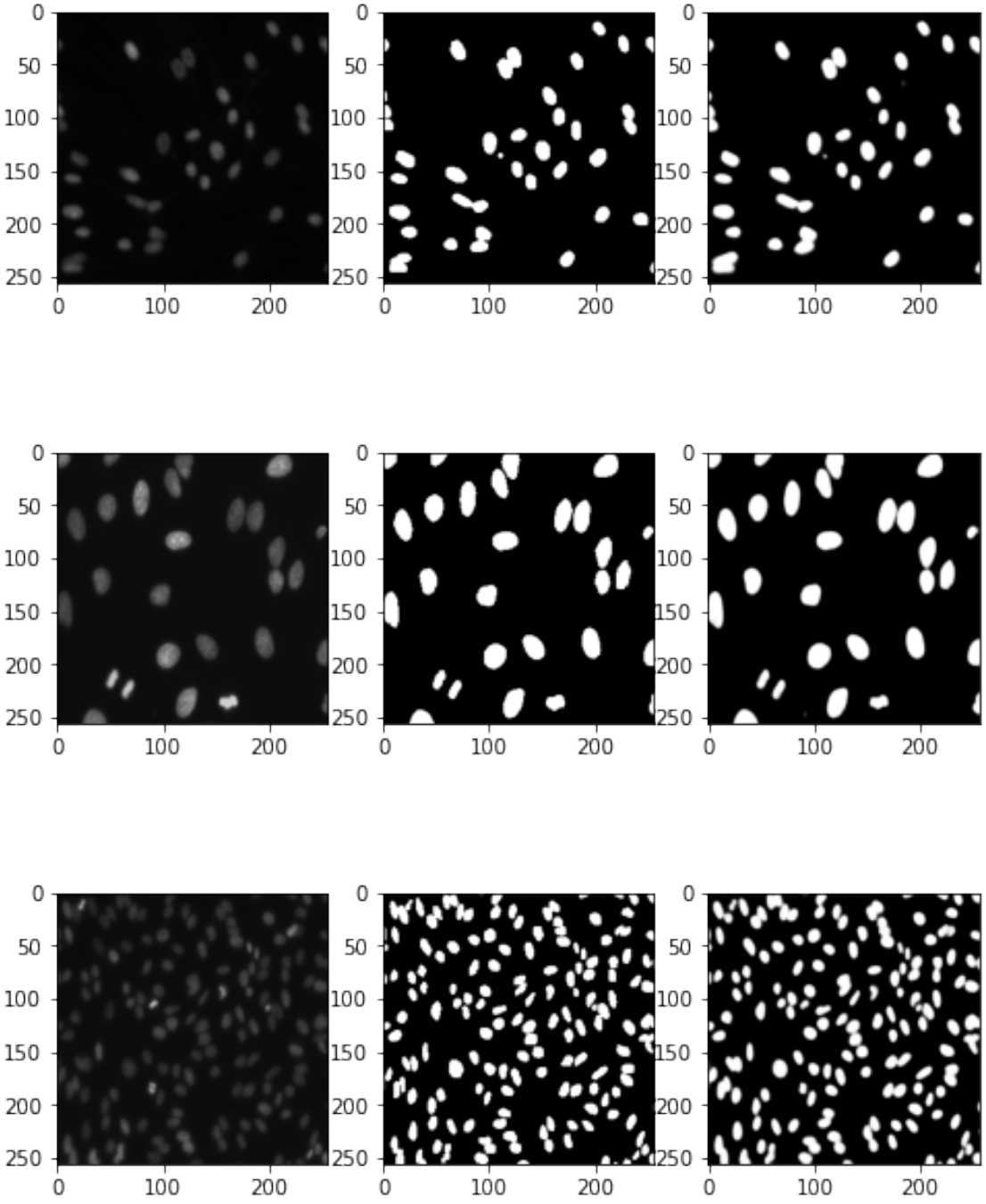
```
<IPython.core.display.Javascript object>
```

6.6 Inference

[34]:
```
for image, mask in val_ds.take(1):
    for i in range(BATCH_SIZE):
        plt.figure(figsize=(8,4))
        plt.subplot(131)
        plt.imshow(image[i])
        plt.subplot(132)
        plt.imshow(mask[i][:,:,0], cmap = 'gray')

        pred_mask  = model.predict(image[i][np.newaxis,:,:,:])
        plt.subplot(133)
        plt.imshow(pred_mask[0,:,:,0], cmap = 'gray')
        plt.show()
```




0
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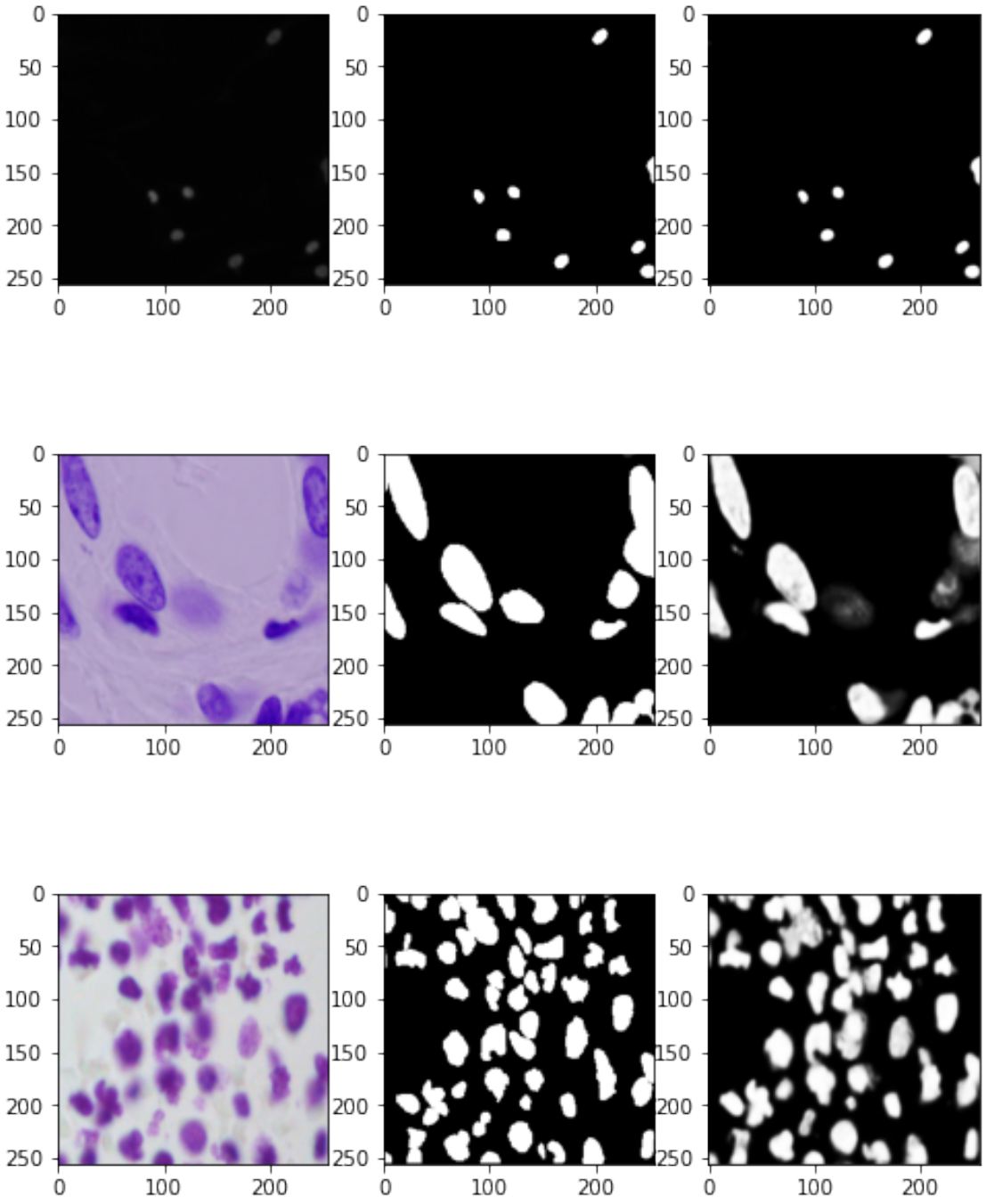
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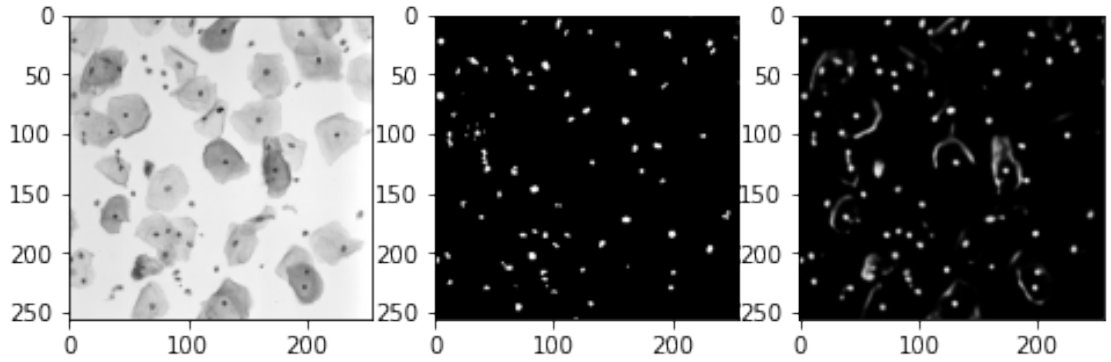
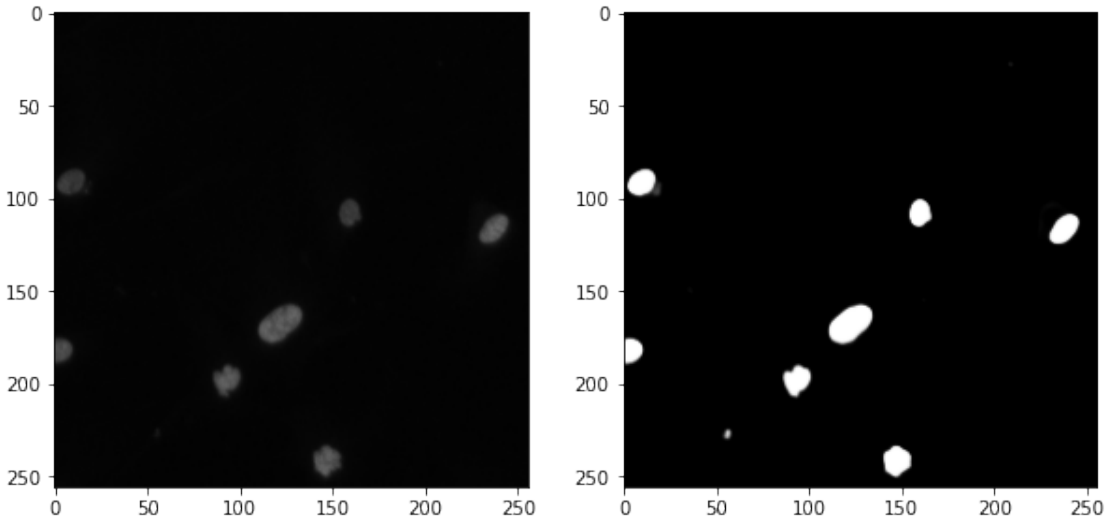
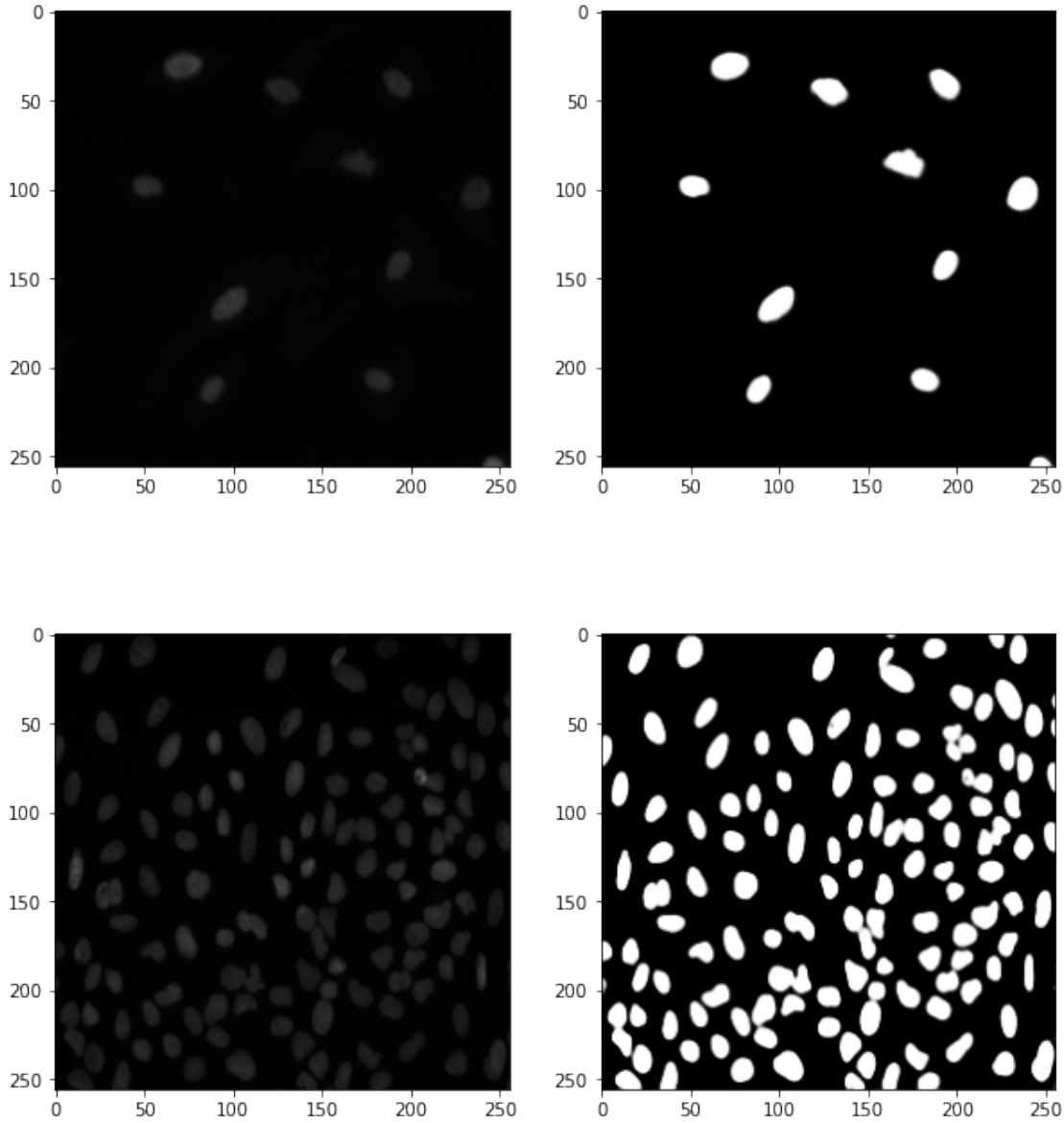


[35]:
```
test_filenames = test_df['files']
for filename in test_filenames[:5]:
    file_path = os.path.join(filename,'images')
    image_path = os.path.join(file_path,os.listdir(file_path)[0])
    image_string = tf.io.read_file(image_path)
    image = tf.image.decode_png(image_string, channels=IMG_CHANNELS)#
    image = tf.image.convert_image_dtype(image, tf.float32)
    image = tf.image.resize(image, [IMG_HEIGHT, IMG_WIDTH]) # height x width

    pred_mask  = model.predict(image[np.newaxis,:,:,:])

    plt.figure(figsize=(10,6))
    plt.subplot(121)
    plt.imshow(image)
    plt.subplot(122)
    plt.imshow(pred_mask[0,:,:,0], cmap='gray')
    plt.show()
```

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250
0
50
100
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0
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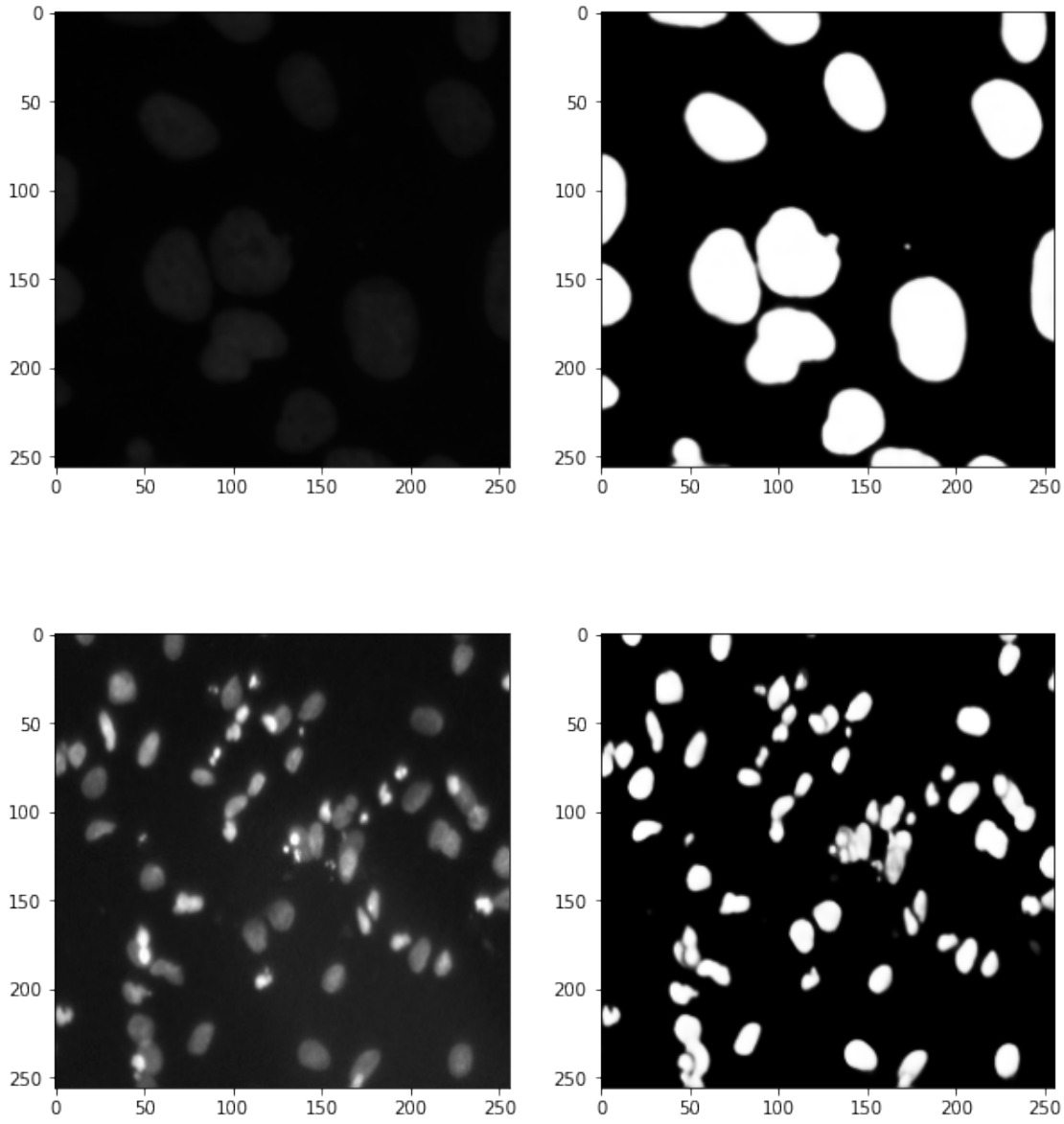
150
200
250



7 EDA

[36]:
```
# Function to create a dataframe with iou_scores and image and mask paths.
def metric_df(data):
    iou_scores = []
    m = MeanIoU(2, 0.4)
    for i in 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 = model.predict(image[np.newaxis,:,:,:])
        m.update_state(mask, pred_mask)
        iou_score = m.result().numpy()
        iou_scores.append(iou_score)
    data['iou_scores'] = iou_scores
    return data
```

[37]:
```
df = X_train.copy()
df = metric_df(df)
df = df.sort_values('iou_scores')
df.head()
```

[37]:

	images	… iou_scores
148	./train/f487cc82271cf84b4414552aa8b0a9d82d902451ebe8e8bc639d4121c1672ff7/images/f487cc82271cf84b4414552aa8b0a9d82d902451ebe8e8bc639d4121c1672ff7.png	… 0.896168
65	./train/adc315bd40d699fd4e4effbcce81cd7162851007f485d754ad3b0472f73a86df/images/adc315bd40d699fd4e4effbcce81cd7162851007f485d754ad3b0472f73a86df.png	… 0.897015
617	./train/a7f767ca9770b160f234780e172aeb35a50830ba10dc49c526f4712451abe1d2/images/a7f767ca9770b160f234780e172aeb35a50830ba10dc49c526f4712451abe1d2.png	… 0.898796
49	./train/10328b822b836e67b547b4144e0b7eb43747c114ce4cacd8b540648892945b00/images/10328b822b836e67b547b4144e0b7eb43747c114ce4cacd8b540648892945b00.png	… 0.900391
306	./train/a31deaf0ac279d5f34fb2eca80cc2abce6ef30bd64e7aca40efe4b2ba8e9ad3d/images/a31deaf0ac279d5f34fb2eca80cc2abce6ef30bd64e7aca40efe4b2ba8e9ad3d.png	… 0.900582

[5 rows x 3 columns]

[38]:
```
df.tail()
```

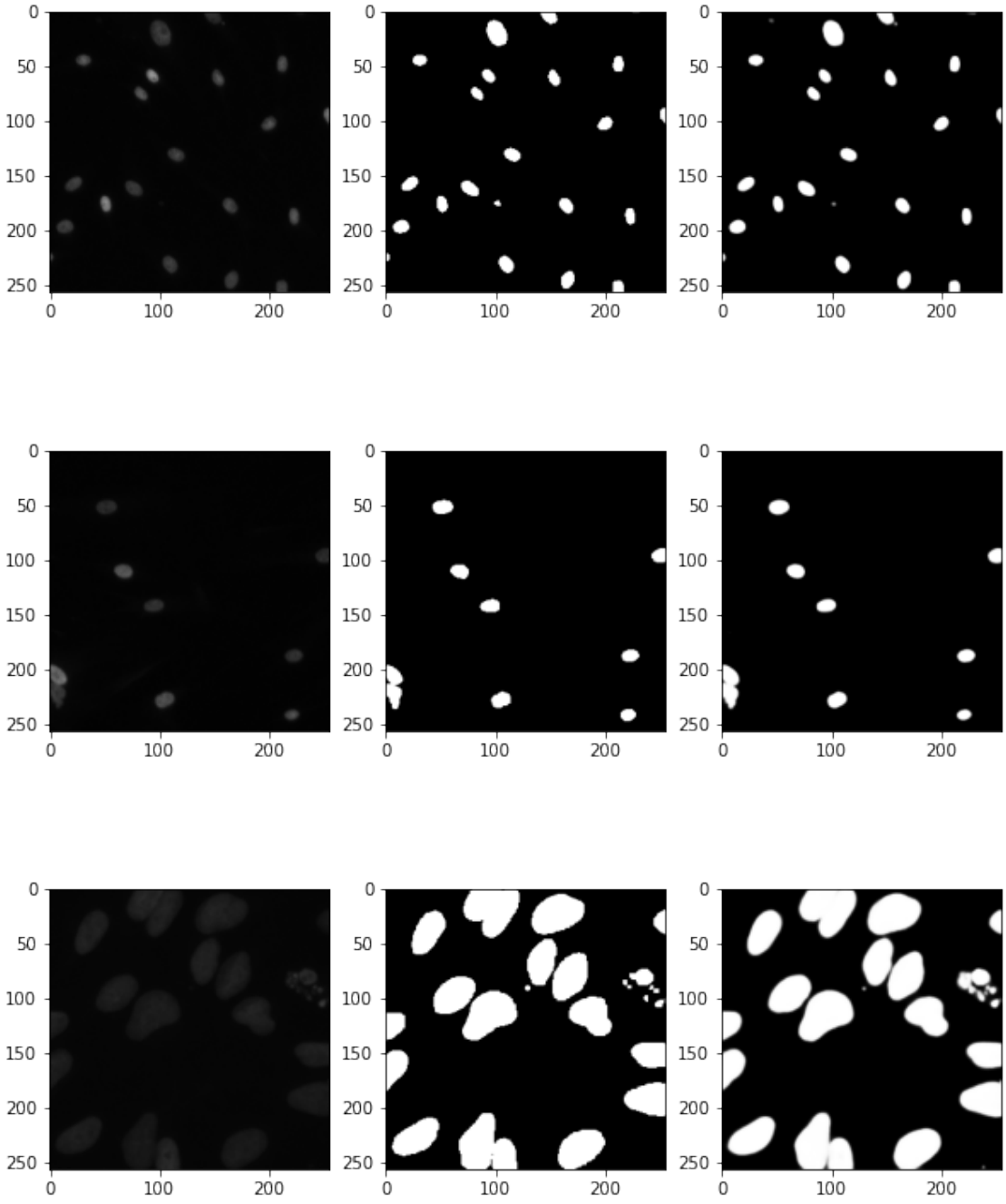
[38]:

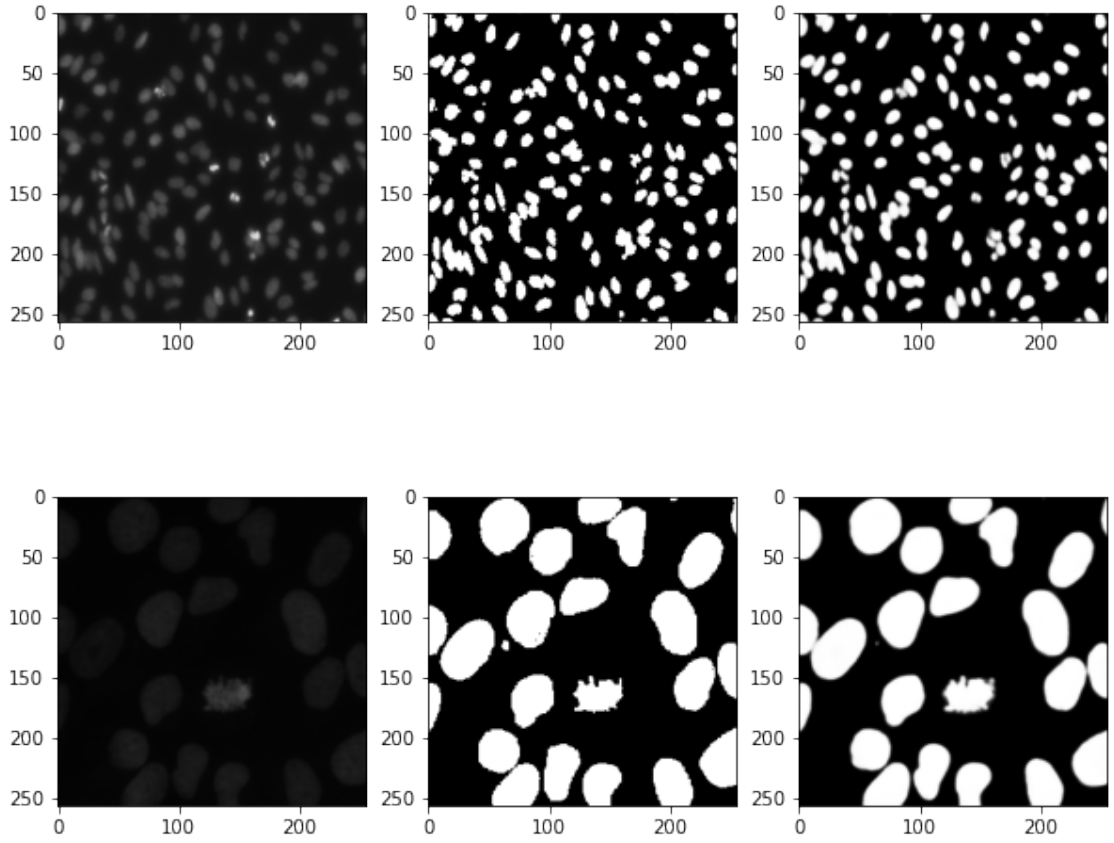
	images	… iou_scores
338	./train/b0d6dfcc95e4d087d232378f860fc3ef9f95ea5a4c26d623a0be091f820a793f/images/b0d6dfcc95e4d087d232378f860fc3ef9f95ea5a4c26d623a0be091f820a793f.png	…

```
0.926667
44   ./train/f35ab34528e3e2d2589d24cbffc0e10024dfc474a68585d0b5feb7b05aa0067f/im
ages/f35ab34528e3e2d2589d24cbffc0e10024dfc474a68585d0b5feb7b05aa0067f.png  …
0.928195
182  ./train/d751ccb64fa767a65a966061218438bd1860695d96bbef11fdb2f0d3b8dedba8/im
ages/d751ccb64fa767a65a966061218438bd1860695d96bbef11fdb2f0d3b8dedba8.png  …
0.930094
60   ./train/b61d3fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895/im
ages/b61d3fb0d0ebbee018346e0adeff9e9178f33aa95262779b3c196f93b4ace895.png  …
0.938454
300  ./train/ac8169a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f/im
ages/ac8169a0debed11560f3f0e246c05ea82d03c66346f1576cc8268554cb3f549f.png  …
0.947107

[5 rows x 3 columns]
```

7.1 Best Output samples

[39]:
```
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  = model.predict(image[np.newaxis,:,:,:])

    plt.figure(figsize=(10,6))
    plt.subplot(131)
    plt.imshow(image)
    plt.subplot(132)
    plt.imshow(mask[:,:,0], cmap='gray')
    plt.subplot(133)
    plt.imshow(pred_mask[0,:,:,0], cmap='gray')
```

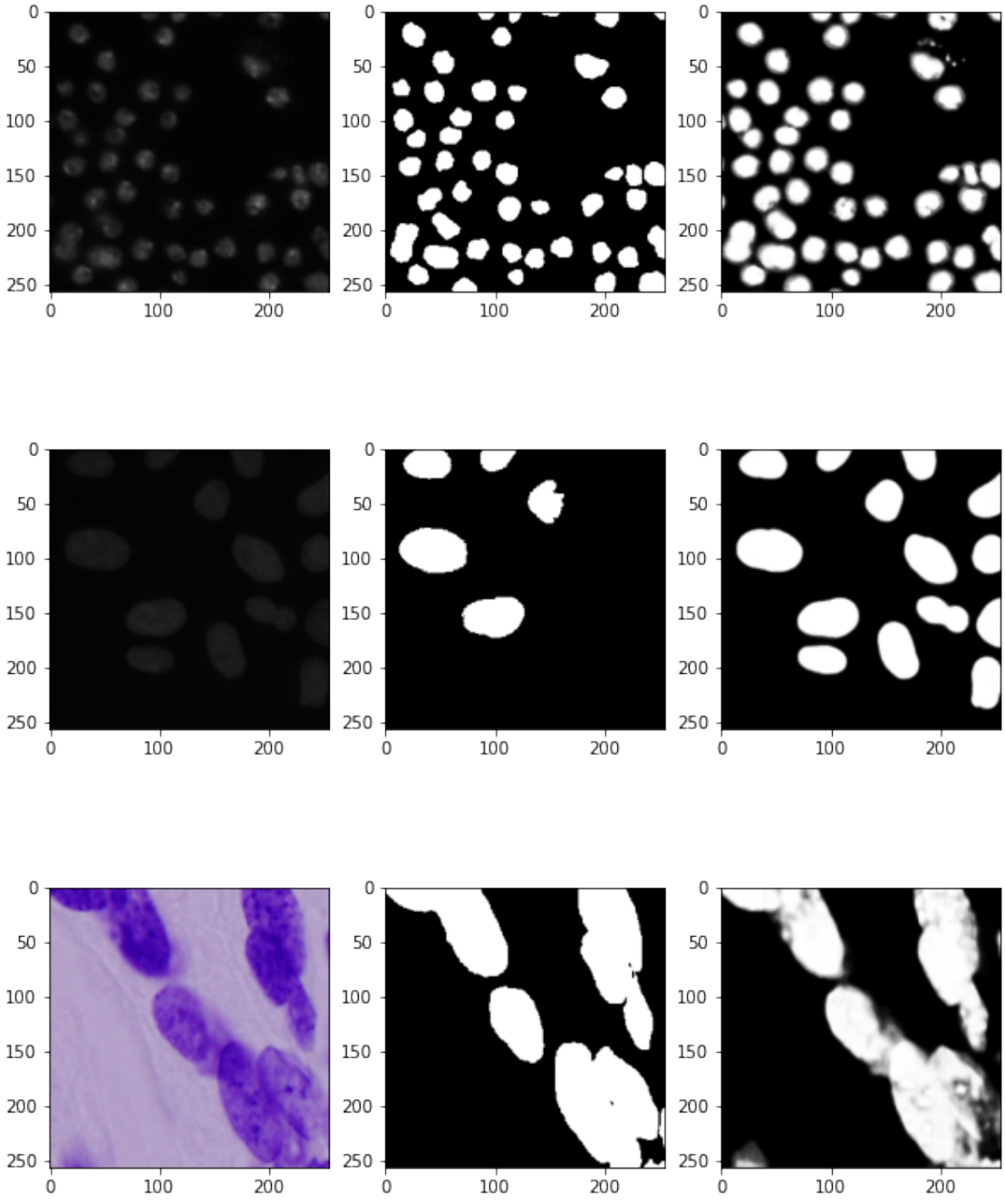

0
50
100
150
200
250
0
100
200

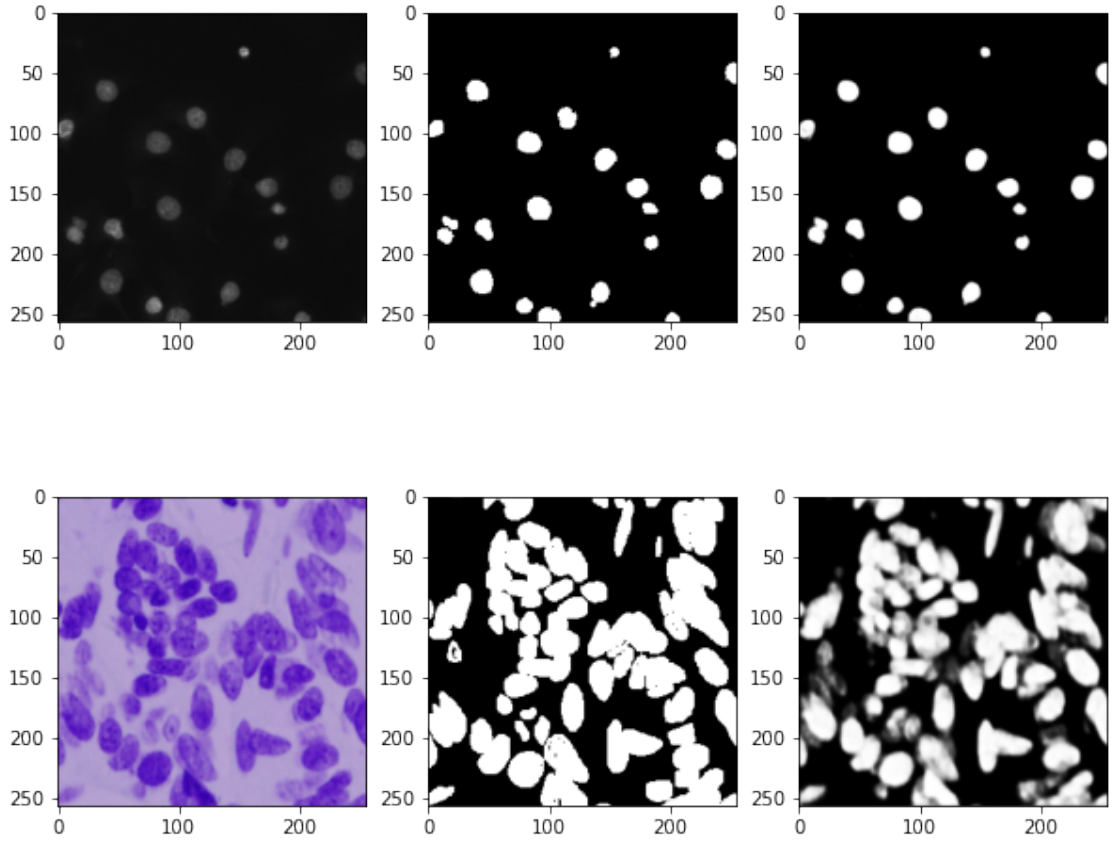


7.2 Worst Output Samples

[40]:
```
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  = model.predict(image[np.newaxis,:,:,:])

    plt.figure(figsize=(10,6))
    plt.subplot(131)
```

```
    plt.imshow(image)
    plt.subplot(132)
    plt.imshow(mask[:,:,0], cmap='gray')
    plt.subplot(133)
    plt.imshow(pred_mask[0,:,:,0], cmap='gray')
    plt.show()
```

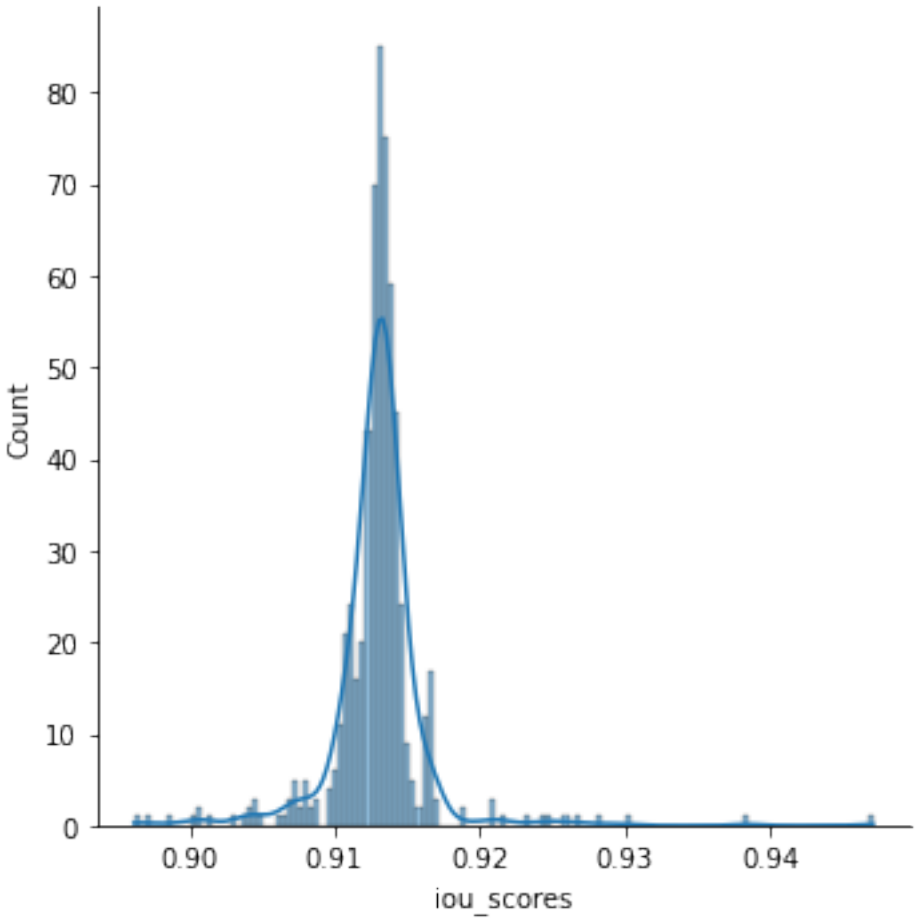




7.3 Distribution of 'iou_scores'

[41]:
```
sns.displot(data=df, x="iou_scores", kde=True)
```

[41]:
```
<seaborn.axisgrid.FacetGrid at 0x7fa0af1b1e10>
```


Count
80
70
60
50
40
30
20
10
0
0.90
0.91
0.92
0.93
0.94
iou_scores