# DeepPhilaOD

Predicting Opioid epidemic progression using incidicence maps generated from EMS radio audio

In [4]:
```
# Import dependencies

from keras.applications.inception_v3 import InceptionV3
from keras.preprocessing import image
from keras.models import Model
from keras.layers import Dense, GlobalAveragePooling2D
from keras import backend as K

import matplotlib.pyplot as plt
import random

import os

import os,sys
import h5py
import pandas as pd
import numpy as np
from keras.preprocessing.image import ImageDataGenerator,array_to_img, img_to_array, load_img
from keras.models import Sequential
from keras.layers import Dropout, Flatten, Dense, Conv2D, MaxPooling2D
from keras import applications
import matplotlib.pyplot as plt
import seaborn as sns
import math
%matplotlib inline
from tqdm import tqdm
from PIL import Image
from keras.applications.mobilenet import preprocess_input
```

## Build model

In [5]:
```
# Load pre-trained model
base_model = InceptionV3(weights='imagenet', include_top=False)
base_model.summary()
```

```
WARNING:tensorflow:From /home/amt353/anaconda3/lib/python3.7/site-packages/tensorflow/python/framework/op_
def_library.py:263: colocate_with (from tensorflow.python.framework.ops) is deprecated and will be removed
in a future version.
Instructions for updating:
Colocations handled automatically by placer.
```

| Layer (type) | Output Shape | Param # | Connected to |
|---|---|---|---|
| input_1 (InputLayer) | (None, None, None, 3 | 0 | |
| conv2d_1 (Conv2D) | (None, None, None, 3 | 864 | input_1[0][0] |
| batch_normalization_1 (BatchNor | (None, None, None, 3 | 96 | conv2d_1[0][0] |
| activation_1 (Activation) | (None, None, None, 3 | 0 | batch_normalization_1[0][0] |
| conv2d_2 (Conv2D) | (None, None, None, 3 | 9216 | activation_1[0][0] |
| batch_normalization_2 (BatchNor | (None, None, None, 3 | 96 | conv2d_2[0][0] |
| activation_2 (Activation) | (None, None, None, 3 | 0 | batch_normalization_2[0][0] |
| conv2d_3 (Conv2D) | (None, None, None, 6 | 18432 | activation_2[0][0] |
| batch_normalization_3 (BatchNor | (None, None, None, 6 | 192 | conv2d_3[0][0] |

- 
- 
- 

```
__________________________________________________________________________________________________
conv2d_88 (Conv2D)              (None, None, None, 3 442368      activation_87[0][0]
__________________________________________________________________________________________________
conv2d_89 (Conv2D)              (None, None, None, 3 442368      activation_87[0][0]
__________________________________________________________________________________________________
conv2d_92 (Conv2D)              (None, None, None, 3 442368      activation_91[0][0]
__________________________________________________________________________________________________
conv2d_93 (Conv2D)              (None, None, None, 3 442368      activation_91[0][0]
__________________________________________________________________________________________________
average_pooling2d_9 (AveragePoo (None, None, None, 2 0           mixed9[0][0]
__________________________________________________________________________________________________
conv2d_86 (Conv2D)              (None, None, None, 3 655360      mixed9[0][0]
__________________________________________________________________________________________________
batch_normalization_88 (BatchNo (None, None, None, 3 1152        conv2d_88[0][0]
__________________________________________________________________________________________________
batch_normalization_89 (BatchNo (None, None, None, 3 1152        conv2d_89[0][0]
__________________________________________________________________________________________________
batch_normalization_92 (BatchNo (None, None, None, 3 1152        conv2d_92[0][0]
__________________________________________________________________________________________________
batch_normalization_93 (BatchNo (None, None, None, 3 1152        conv2d_93[0][0]
__________________________________________________________________________________________________
conv2d_94 (Conv2D)              (None, None, None, 1 393216      average_pooling2d_9[0][0]
__________________________________________________________________________________________________
batch_normalization_86 (BatchNo (None, None, None, 3 960         conv2d_86[0][0]
__________________________________________________________________________________________________
activation_88 (Activation)      (None, None, None, 3 0           batch_normalization_88[0][0]
__________________________________________________________________________________________________
activation_89 (Activation)      (None, None, None, 3 0           batch_normalization_89[0][0]
__________________________________________________________________________________________________
activation_92 (Activation)      (None, None, None, 3 0           batch_normalization_92[0][0]
__________________________________________________________________________________________________
activation_93 (Activation)      (None, None, None, 3 0           batch_normalization_93[0][0]
__________________________________________________________________________________________________
batch_normalization_94 (BatchNo (None, None, None, 1 576         conv2d_94[0][0]
__________________________________________________________________________________________________
activation_86 (Activation)      (None, None, None, 3 0           batch_normalization_86[0][0]
__________________________________________________________________________________________________
mixed9_1 (Concatenate)          (None, None, None, 7 0           activation_88[0][0]
                                                                 activation_89[0][0]
__________________________________________________________________________________________________
concatenate_2 (Concatenate)     (None, None, None, 7 0           activation_92[0][0]
                                                                 activation_93[0][0]
__________________________________________________________________________________________________
activation_94 (Activation)      (None, None, None, 1 0           batch_normalization_94[0][0]
__________________________________________________________________________________________________
mixed10 (Concatenate)           (None, None, None, 2 0           activation_86[0][0]
                                                                 mixed9_1[0][0]
                                                                 concatenate_2[0][0]
                                                                 activation_94[0][0]
==================================================================================================
Total params: 21,802,784
Trainable params: 21,768,352
Non-trainable params: 34,432
__________________________________________________________________________________________________
```

In [6]:
```
#-Transfer learning

from keras.layers import Conv1D

# Freeze all InceptionV3 layers
for layer in base_model.layers:
    layer.trainable = False

# Get output tensors to prepare for adding layers
x = base_model.output

# Add a few Dense and Dropout layers for initial "learning"
for i in range(10):
    x = Dense(1024, activation='relu')(x)
    x = Dropout(0.2)(x)

# Hope for feature selection when weights are adjusted in the fitting/ retraining
for i in range(10):
    x = Conv2D (kernel_size = (200), filters = 20, activation='relu')(x)
    x = MaxPooling2D(pool_size = (1,10), strides=(1,2))(x)

# Final predictive layer -- supposed to be 47 predictions, one for value per zip code
# --total is 87 zip codes, but bug from above, so only 5 (otherwise model won't build)
predictions = Dense(5, activation='relu')(x)

# this is the model we will train
deepPhilaOD = Model(inputs=base_model.input, outputs=predictions)

# compile to allow for fitting with new data
deepPhilaOD.compile(optimizer='Adam',loss='categorical_crossentropy',metrics=['accuracy'])
```

```
WARNING:tensorflow:From /home/amt353/anaconda3/lib/python3.7/site-packages/keras/backend/tensorflow_backen
d.py:3445: calling dropout (from tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be re
moved in a future version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
```

- Note: not very sure which line or call resulted in the message above, but the model builds
- Future work: debug and continue optimizing

## Training and testing

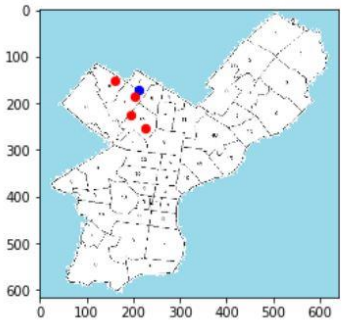
In [69]:
```
# Initiate list of zip codes (47 as shown in most zip-code-maps)
zips = [19142, 19128, 19118, 19140, 19148, 19102, 19152, 19154, 19145,
          +19120 , 19141 , 19149, 19136, 19114, 19115, 19146, 19130, 19107, 19122, 19106,
          +19143, 19112, 19103, 19133, 19124, 19153, 19131, 19104, 19121, 19144, 19150,
          +19123, 19125, 19111, 19151, 19139, 19126, 19134, 19137, 19127, 19129, 19132,
          +19119, 19147,19138, 19135, 19116]
```

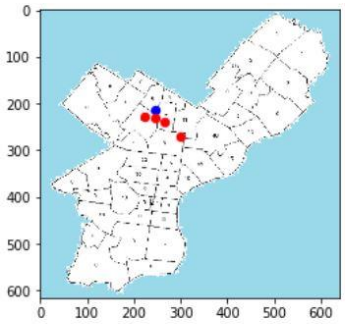
In [72]:
```
# Prepare folders for zip codes: catch generated toy data
for z in zips:
    os.mkdir('data/'+str(z))
```

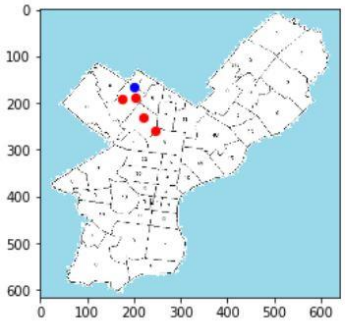
In [73]:
```
# Get ready to generate toy data
im = plt.imread('philaZip.png')
```

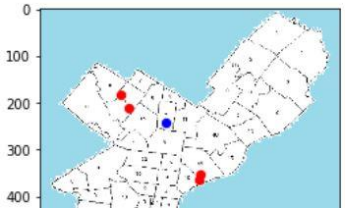
In [74]:
```
# Functions for generating toy data
def rand_hot( ):
    '''Input: none; Output: one x coordinate for zip code'''
    return random.randint(150,350)

def x2y_adjust( xs ):
    '''Input: list of x; Output: list of ys'''
    return [math.ceil(x*(1+random.uniform(-0.1,0.15))) for x in xs]
```

In [81]:
```
# Generate toy data

#blue: bx = [210]; by= [150]
#red: rx=[320, 280], ry=[300, 330]

for z in zips:
    for i in range(191):
        implot = plt.imshow(im)
        cx = random.randint(200,400)
        cy = cx*random.uniform(0.8,0.9)
        # put a blue dot at (10, 20)
        plt.scatter(cx, cy, c='b', s=40)

        bx = [rand_hot() for i in range(4) ]
        by = x2y_adjust(bx)

        # put a red dot, size 40, at 2 locations:u
        plt.scatter(bx, by, c='r', s=40)
        plt.savefig(f'data/{z}/text_map{i}.png',dpi=200)

        plt.show()
```



- Note: Only a few toy data shown since this jupyter notebook became too big to push

In [7]:
```
# Data processing

train_datagen=ImageDataGenerator(preprocessing_function=preprocess_input) #included in our dependencies

train_generator=train_datagen.flow_from_directory('.',
                                                  target_size=(224,224),
                                                  color_mode='rgb',
                                                  batch_size=10,
                                                  class_mode='categorical',
                                                  shuffle=True)
```

```
Found 9008 images belonging to 5 classes.
```

- Note: BUG! Desired number of classes is 47, the number of zip codes shown on most zip-code-maps
- Possible bug when calling ImageDataGenerator: preprocess_input function from Keras MobileNet model

In [96]:
```
# Retrain model with new data
deepPhilaOD.fit_generator(generator=train_generator,
                          steps_per_epoch=150,
                          epochs=5)
```

```
Epoch 1/5
150/150 [==============================] - 194s 1s/step - loss: 1.1921e-07 - acc: 1.0000
Epoch 2/5
150/150 [==============================] - 180s 1s/step - loss: 1.1921e-07 - acc: 1.0000
Epoch 3/5
150/150 [==============================] - 173s 1s/step - loss: 0.0107 - acc: 0.9993
Epoch 4/5
150/150 [==============================] - 177s 1s/step - loss: 1.1921e-07 - acc: 1.0000
Epoch 5/5
150/150 [==============================] - 176s 1s/step - loss: 1.1921e-07 - acc: 1.0000
```

Out[96]:
```
<keras.callbacks.History at 0x7f0ef45d5a90>
```

- Note: training performed on dummy data is expected to be inaccurate
- Possible explanation: the greatly decreased number of expected categories (47, not 5) might be responsible for the inflated accuracy

## Prediction for a new image

In [ ]:
```
# New image!
path_new_im = 'staticmap.png'
im_loaded= image.load_img(path_new_im, target_size=(224, 224))
new_im_a = image.img_to_array( im_loaded )
new_im = np.expand_dims( new_im_a, axis=0 )
new_im = preprocess_input( new_im )

# Prediction
new_pred = deepPhilaOD.predict( new_im )
```

In [122]:
```
import pandas as pd
elems = (np.array([1, 2, 3]), np.array([-1, 1, -1]))
pred_df = pd.DataFrame( new_pred, columns=['19104','19111', '19137','19119','19145'], index = ['Pred_val'
])
```

In [123]:
```
pred_df
```

Out[123]:

| | 19104 | 19111 | 19137 | 19119 | 19145 |
|---|---|---|---|---|---|
| **Pred_val** | 0.0 | 0.0 | 59.910152 | 0.0 | 0.0 |