

# Interpreting\_Image\_Classification

July 9, 2019

## 1 Interpreting Image Classification of Keras InceptionV3

This notebook examines the predictions of an image classifier (CNN InceptionV3) using two interpretation methods:

- LimeImageExplainer (LIME)
  - Class Activation Maps (CAM)
- First, LIME and CAM will be applied on a single prediction to make their concepts easier to understand.
  - In the following section, both methods are systematically applied to a group of predictions and compared using their masks
  - The Images used in this notebook can be downloaded from ImageNet: [Download from here](#)

```
[1]: #process not on GPU
import os
os.environ['CUDA_VISIBLE_DEVICES'] = ''
```

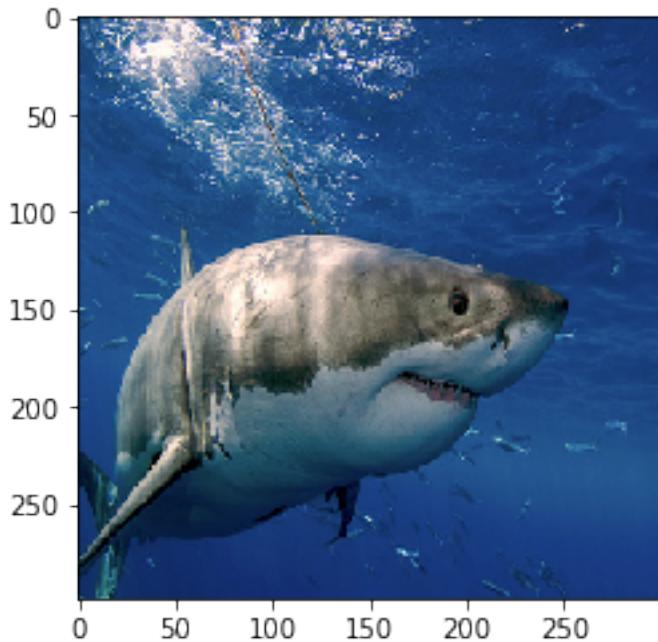
```
[2]: # Keras
import keras
from keras.applications.inception_v3 import InceptionV3, preprocess_input,decode_predictions
from keras.preprocessing.image import load_img, img_to_array
# Tools requiered for visualizing and processing
import matplotlib.pyplot as plt
import pandas as pd
```

```
[4]: import warnings
warnings.filterwarnings('ignore')
```

```
[5]: model_InceptionV3 = InceptionV3(weights = 'imagenet')
```

```
[6]: # Load image and scale to 299x299
image_raw = load_img("/home/common_files/datasets/imagenet/bounding_boxes/n01484850/n01484850_10798.jpg",target_size = (299,299))
plt.imshow(image_raw)
```

```
[6]: <matplotlib.image.AxesImage at 0x7f869199e550>
```



```
[7]: # Preprocess image in an array to make it compatible with the Keras model and ↴ reshape it.
image = img_to_array(image_raw)
image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
image = preprocess_input(image)

[8]: # Predict label of image
prediction = model_InceptionV3.predict(image)
pd.DataFrame(decode_predictions(prediction, ↴ top=3)[0], columns=['col1', 'class', 'probability']).iloc[:,1:]

[8]:
      class  probability
0  great_white_shark    0.938497
1        tiger_shark    0.001046
2       grey_whale     0.000489

[9]: import lime
from lime.lime_image import LimeImageExplainer
# Required segmentation package for creating superpixel of image
from skimage.segmentation import mark_boundaries, quickshift
import numpy as np

[10]: explainer = LimeImageExplainer()

[11]: # This part is optional and is listed to make clear the idea behind ↴ LimeImageExplainer. This means Lime does this automatically in the back.
```

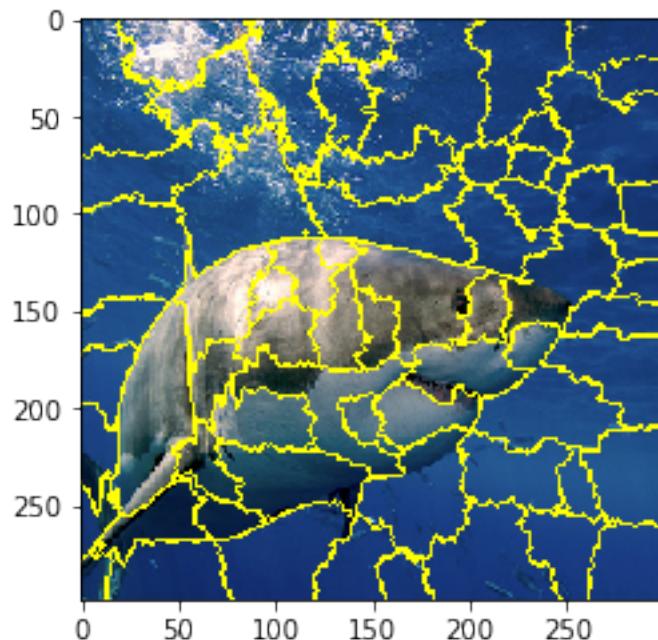
```

# Lime is creating superpixels using the segmentation algorithm quickshift like
# below, and predicts the image user-defined-times by turning superpixel on
# and off

segments = quickshift(image_raw, kernel_size=4, max_dist=200, ratio=0.
                      ↪2,random_seed=42)
superpixel = mark_boundaries(image_raw, segments)
plt.imshow(superpixel)
print('Number of superpixel: ',len(np.unique(segments)))

```

Number of superpixel: 65



[12]:

```

# pass image as (299,299,3)-Array 299x299Pixel in RGB
# top_labels = 3 -> create explanation for top three labels predicted by the
# model for image
# num_samples = 500 -> create 500 similiar pictures by turning superpixel on
# and off
# random_seed = 42 -> for reproducability of segmenation (superpixel)

explanation = explainer.explain_instance(image[0], model_InceptionV3.predict,
                                           ↪top_labels=3, num_samples=500, random_seed=42)

```

[13]:

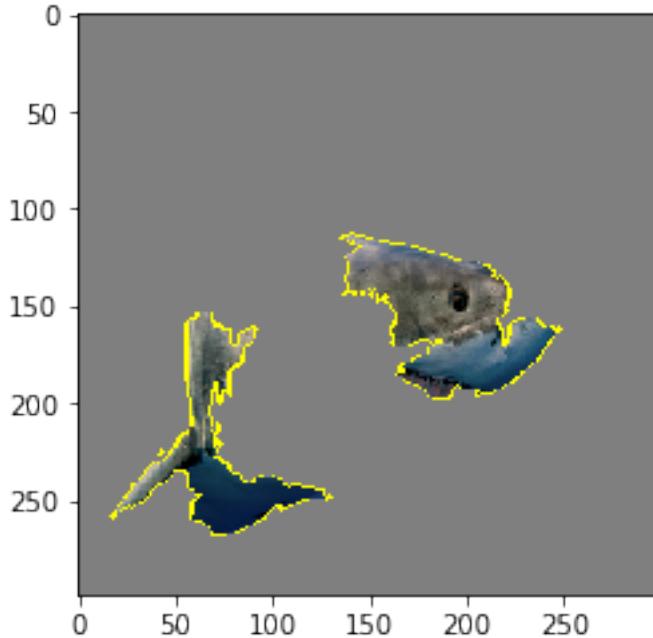
```

# Show top five (by default) Superpixel with positive weights supported
# decision making

```

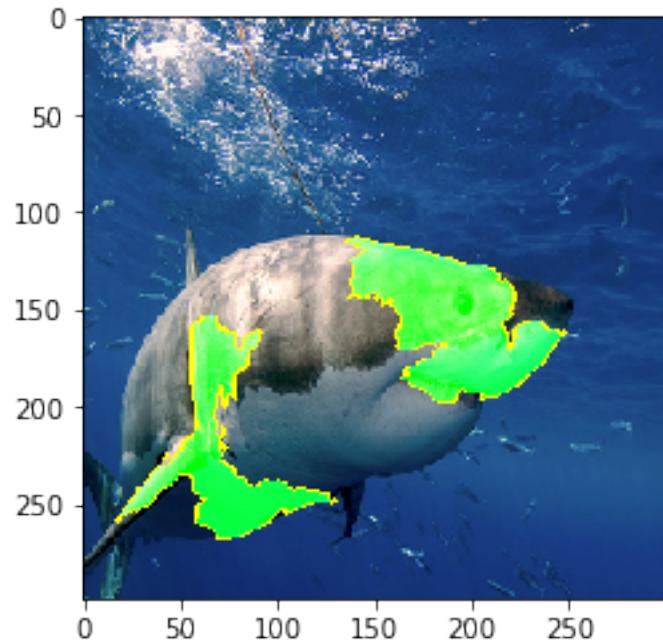
```
temp, mask = explanation.get_image_and_mask(explanation.top_labels[0],  
    positive_only=True, hide_rest=True)  
top_superpixels = mark_boundaries(temp /2 + .5,mask)  
plt.imshow(top_superpixels)
```

[13]: <matplotlib.image.AxesImage at 0x7f86858553c8>



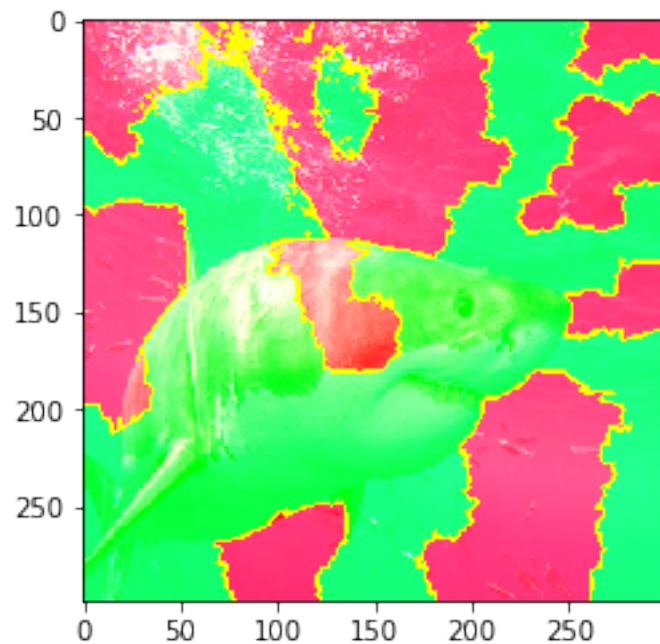
```
[14]: # explanation.top_labels[0] -> index of highest probable predicted class  
temp, mask = explanation.get_image_and_mask(explanation.top_labels[0],  
    positive_only=False, hide_rest=False)  
top_superpixels = mark_boundaries(temp /2 + .5,mask)  
plt.imshow(top_superpixels)
```

[14]: <matplotlib.image.AxesImage at 0x7f86857a14a8>



```
[15]: temp, mask = explanation.get_image_and_mask(explanation.top_labels[0],  
    positive_only=False, num_features=len(np.unique(segments)), hide_rest=False)  
top_superpixels = mark_boundaries(temp / 2 + .5, mask)  
plt.imshow(top_superpixels)
```

```
[15]: <matplotlib.image.AxesImage at 0x7f8685784860>
```



```
[16]: results_images_df = pd.read_hdf('results-inceptionv3-1.h5',key='pictures')
results_images_df.sort_values(['confidence_difference'], ascending=False).
    head(5)

[16]:   label_id  label_name1      label_name2  prediction_id  prediction_name1 \
0        207  n02099601  golden_retriever          971  n09229709
0        207  n02099601  golden_retriever          475  n02965783
0        263  n02113023           Pembroke          805  n04254680
0        541  n03249569            drum          822  n04311174
0       880  n04509417        unicycle          475  n02965783

      prediction_name2      file_name  confidence_in_prediction \
0             bubble  n02099601/n02099601_4933.jpg                 1.0
0        car_mirror  n02099601/n02099601_2077.jpg                 1.0
0    soccer_ball  n02113023/n02113023_8857.jpg                 1.0
0    steel_drum  n03249569/n03249569_14988.jpg                 1.0
0        car_mirror  n04509417/n04509417_1366.jpg                 1.0

  prediction_in_top_5  confidence_in_label  confidence_difference
0              False      2.533398e-08                  1.0
0              False      4.801222e-11                  1.0
0              False      1.617717e-08                  1.0
0              False      2.191712e-08                  1.0
0              False      5.660312e-10                  1.0

[17]: %%html
<style>
table {float:left}
</style>
```

<IPython.core.display.HTML object>

### 1.0.1 Columns of dataset explained

Column	Explanation
label_id	index of actual label
label_name1	encoded actual label
label_name2	decoded actual label
prediction_id	index of predicted label
prediction_name1	encoded predicted label
prediction_name2	decoded predicted label
file_name	directory of image
confidence_in_prediction	probability for predicted label by model
prediction_in_top_5	True, if actual label is in top five of predicted classes, otherwise False

Column	Explanation
confidence_in_label	probability for actual label predicted by model
confidence_difference	confidence_in_prediction - confidence_in_label

```
[18]: # To load images
def get_image(image_dir):
    image = load_img("/home/common_files/datasets/imagenet/pictures/
→"+image_dir,target_size = (299,299))
    return image

[19]: # Preprocess image in an array to make it compatible with the Keras model and
→reshape it.
def preprocess_image(image_raw):
    image = img_to_array(image_raw)
    image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
    image = preprocess_input(image)
    return image[0]

[20]: # Create explanation of Image
def explanation_for_instance(image,model):
    explanation = explainer.explain_instance(image,model.predict,top_labels =
→1,num_samples=500,random_seed=42)
    return explanation

[21]: # Mask explanation and return top ten superpixel for most probable prediction
→of model and hide rest of image
def get_explained_image(explanation, positive_only, hide_rest):
    temp, mask = explanation.get_image_and_mask(explanation.top_labels[0],u
→positive_only = positive_only, num_features=10, hide_rest=hide_rest)
    boundaries = mark_boundaries(temp /2 + .5,mask)
    return boundaries
```

### 1.0.2 Create explanation in loop

- We want to create explanations for only images where confidence\_difference is higher than 0.98 since we have more than 100 000 false predictions
- And it takes too much time generate an explanation for an image

```
[22]: # Order dataframe by confidence_difference descending to make iteration more
→efficient
results_images_df = results_images_df.sort_values(['confidence_difference'],u
→ascending=False)

# Create explanation in loop
```

```

for i in range(len(results_images_df)):

    file_name = results_images_df.iloc[i]['file_name']
    image_raw = get_image(file_name)
    image = preprocess_image(image_raw)
    # Create explanation for predicted label
    explanation = explanation_for_instance(image, model_InceptionV3)
    # get explained image with 10 positive weighted superpixel and hide rest
    explained_image_positive_and_hidden = get_explained_image(explanation, □
    →positive_only = True, hide_rest= True)
    # get explained image with 10 positive or negative weighthed superpixel, □
    →hide_rest = False
    explained_image_pos_neg = get_explained_image(explanation, positive_only = □
    →False, hide_rest= False)

    #plt.savefig('..../Output_Images/Predicted_ {}, Actual_ {}'.format(results_images_df.iloc[i]['prediction_name2'],results_images_df.iloc[i]['label_name2']))

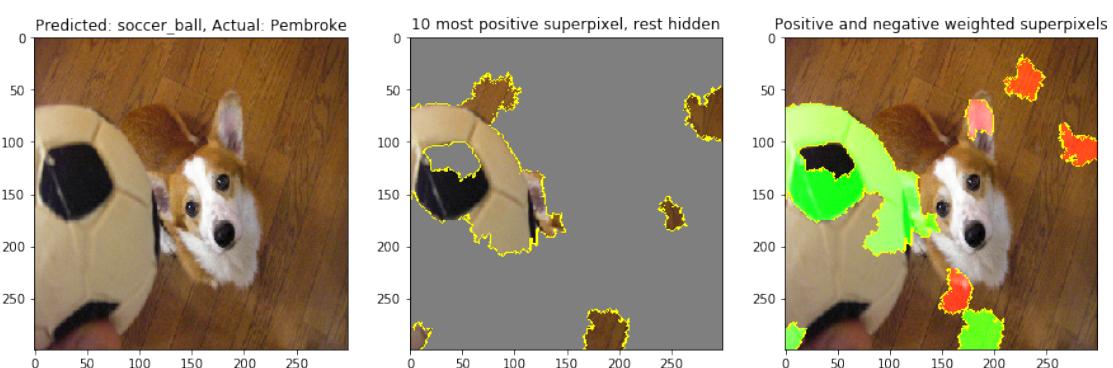
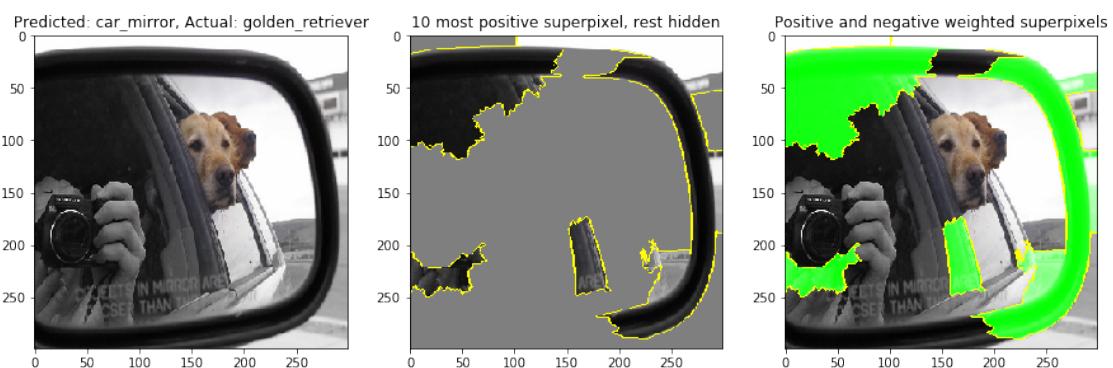
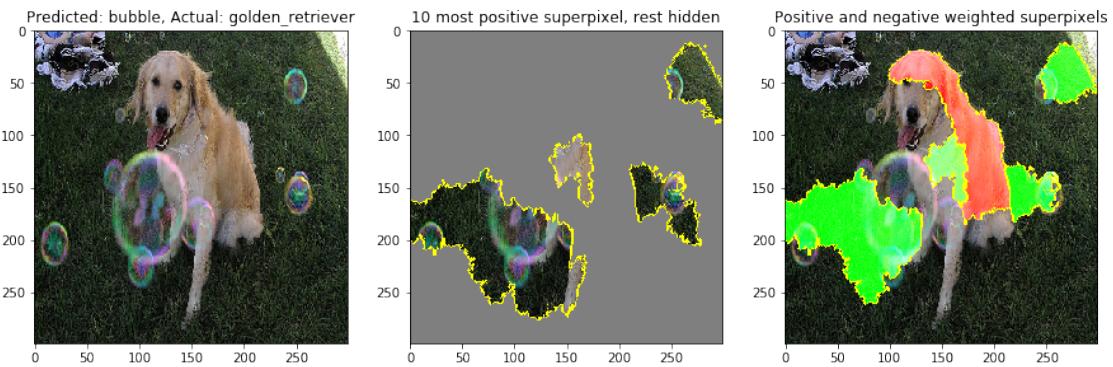
    #plot only first 10
    if i < 10:

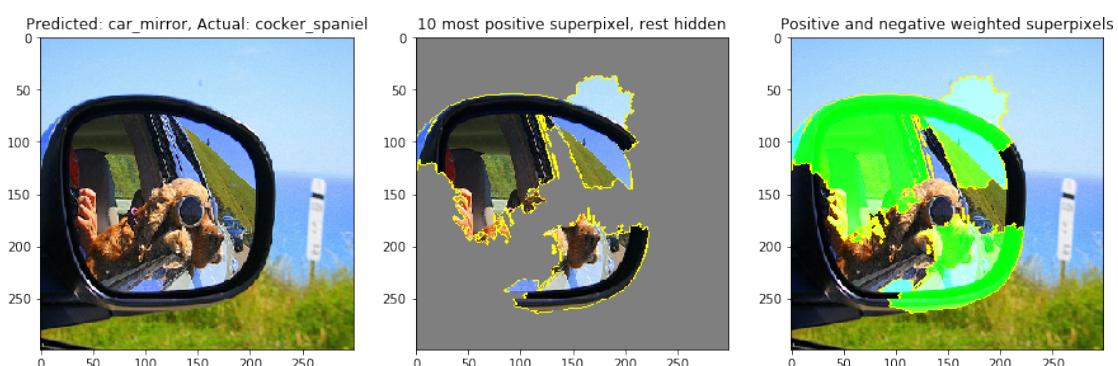
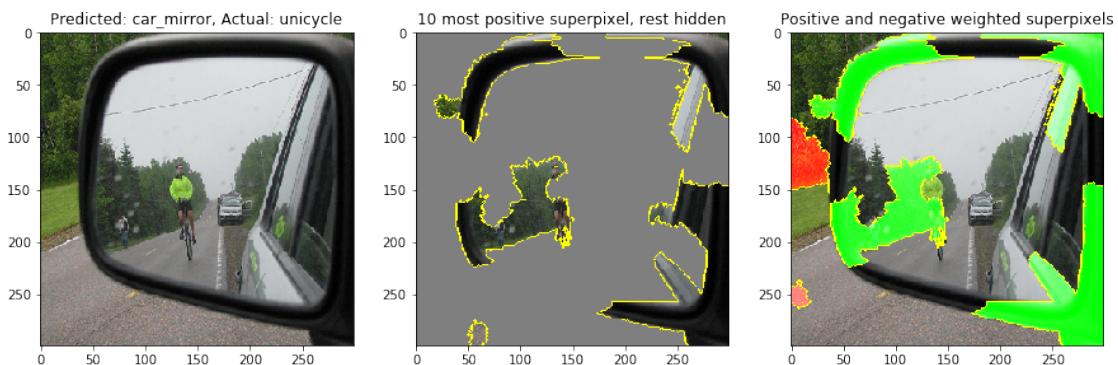
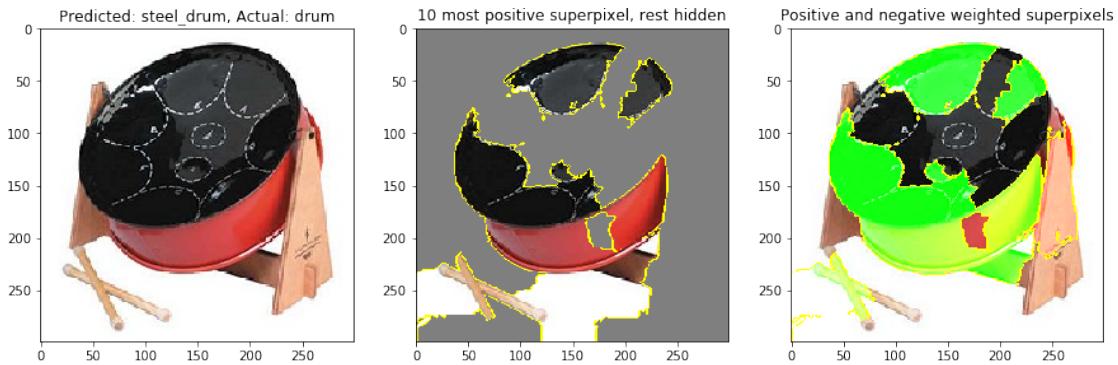
        fig, ax = plt.subplots(1,3, figsize = (15,15))
        ax[0].imshow(image_raw)
        ax[0].set_title('Predicted: {}, Actual: {}'.format(results_images_df.iloc[i]['prediction_name2'],results_images_df.iloc[i]['label_name2']),□
        →fontsize =12)
        ax[1].imshow(explained_image_positive_and_hidden)
        ax[1].set_title('10 most positive superpixel, rest hidden')
        ax[2].imshow(explained_image_pos_neg)
        ax[2].set_title('Positive and negative weighted superpixels')
        plt.show()

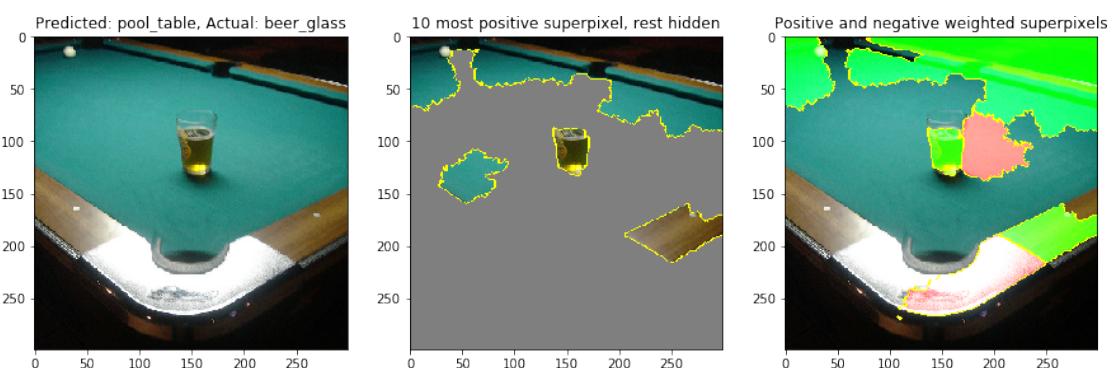
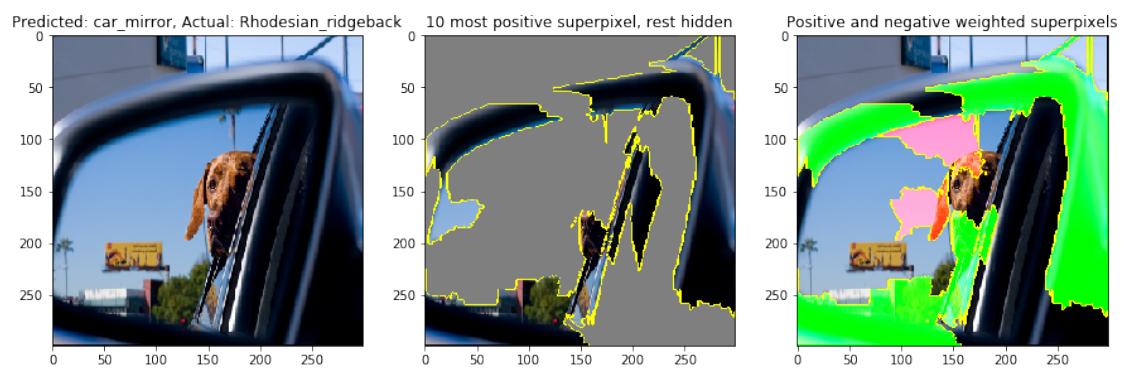
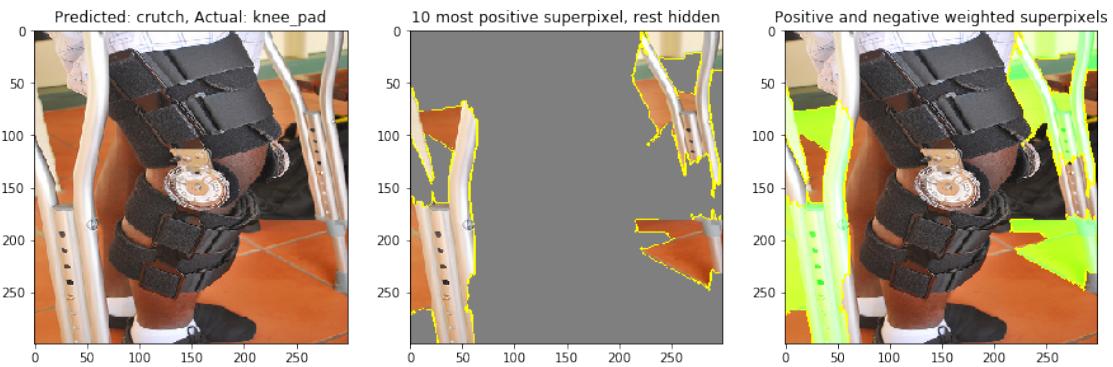
    if results_images_df.iloc[i]['confidence_difference'] < 0.98:
        break

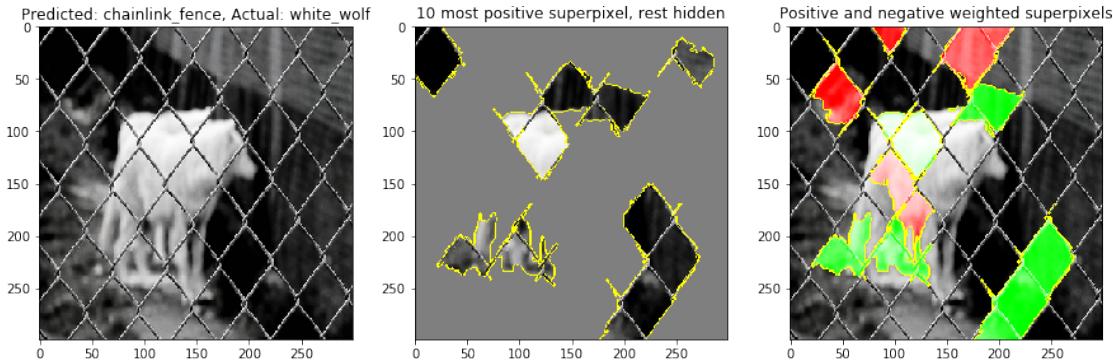
    if i >=10:
        break

```









## 1.1 Lime vs Class Activation Maps

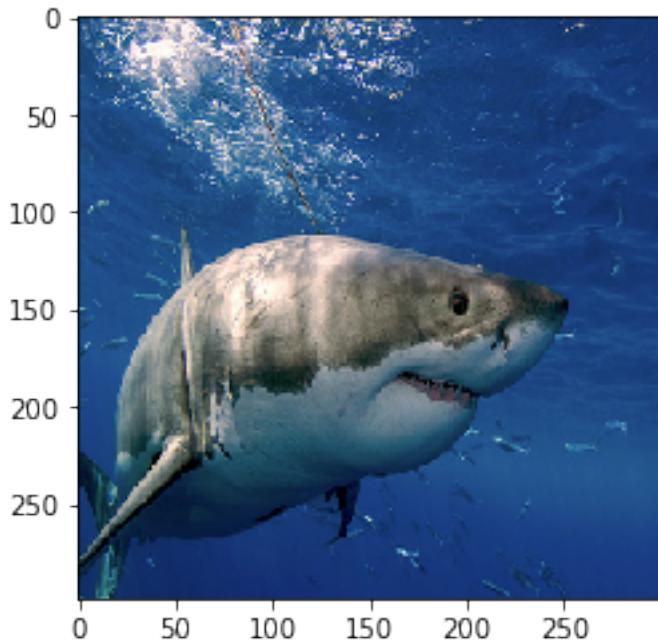
- In this section Class Activation Maps are generated and compared with the results of the LimeImageExplainer.
- Class Activation Maps are simple to implement and can help to get the discriminative image regions used by a CNN to identify a specific class in the image.
- Class Activation Maps are often called as Attention Maps

### 1.1.1 Get Class Activation Map for a single prediction

```
[23]: # import keras-vis
import vis
from vis.utils import utils
from vis.visualization import overlay, visualize_cam
from keras import activations
import os
import xml.etree.ElementTree as ET
import matplotlib.patches as patches
import h5py
import seaborn as sns
import json

[24]: image_raw = load_img("/home/common_files/datasets/imagenet/bounding_boxes/
    ↳n01484850/n01484850_10798.jpg",target_size = (299,299))
plt.imshow(image_raw)

[24]: <matplotlib.image.AxesImage at 0x7f867e278eb8>
```



```
[25]: image = img_to_array(image_raw)
image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
image = preprocess_input(image)
```

```
[26]: prediction = model_InceptionV3.predict(image)
print(pd.DataFrame(decode_predictions(prediction,
                                       top=3)[0], columns=['class', 'probability']).iloc[:,1:])
# get corresponding imagenet index for prediction
argmax = np.argmax(prediction[0])
print('\nImageNet Index for prediction: ', argmax)
```

	class	probability
0	great_white_shark	0.938497
1	tiger_shark	0.001046
2	grey_whale	0.000489

ImageNet Index for prediction: 2

```
[27]: # get last layer
prediction_layer = model_InceptionV3.get_layer('predictions')
print(prediction_layer)
```

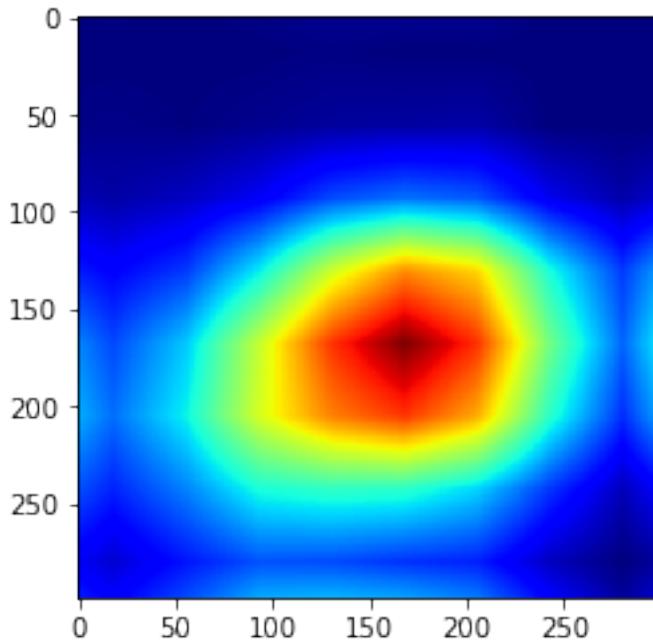
<keras.layers.core.Dense object at 0x7f86928811d0>

```
[28]: # get index of last layer
prediction_layer_idx = utils.find_layer_idx(model_InceptionV3, 'predictions')
print(prediction_layer_idx)
```

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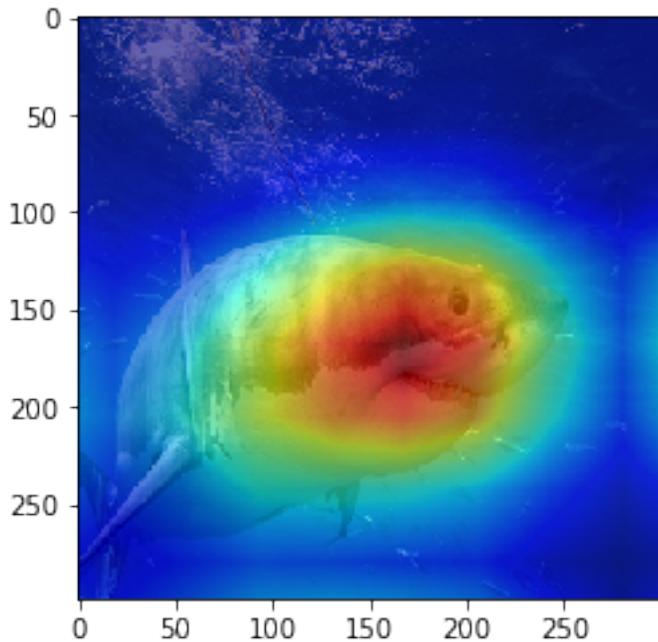
```
[29]: cam = visualize_cam(model=model_InceptionV3, layer_idx=prediction_layer_idx, ↴filter_indices=argmax, seed_input=image)
plt.imshow(cam)
cam.shape
```

[29]: (299, 299, 3)



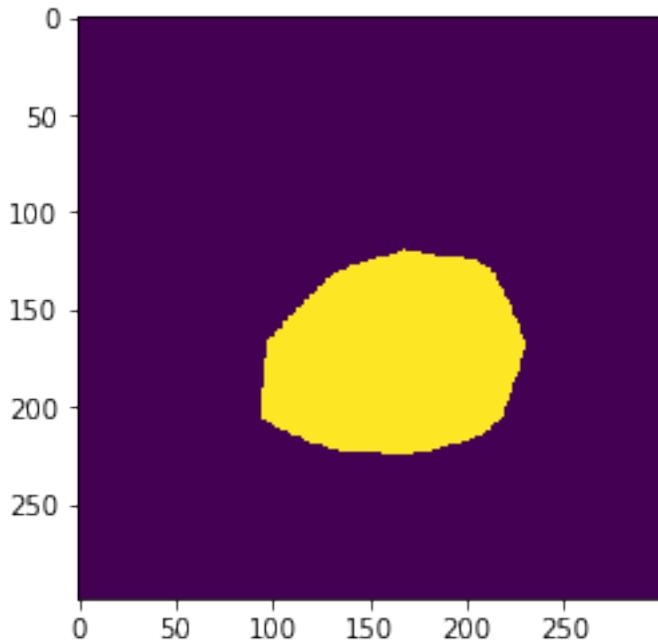
```
[30]: plt.imshow(overlay(np.array(image_raw),cam, alpha=0.4))
```

[30]: <matplotlib.image.AxesImage at 0x7f867e0aa518>



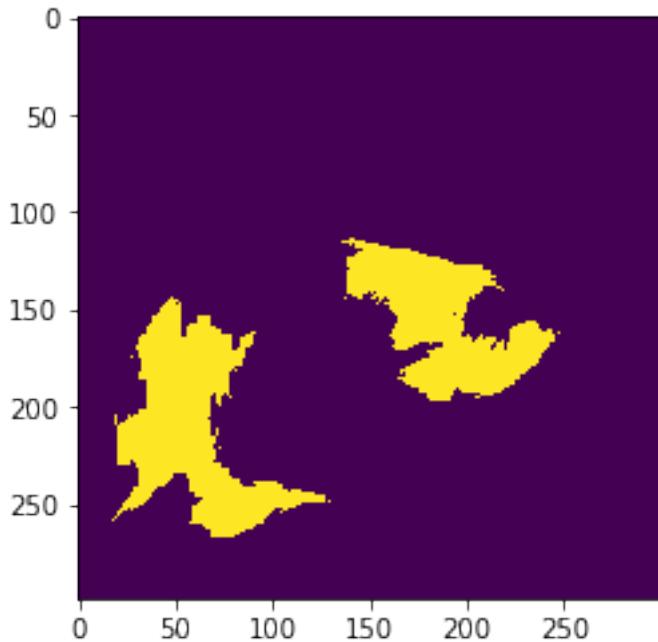
```
[31]: # Get the red area of the attention_map (most positive area for classification  
→of cnn)  
# where blue channel is under 100  
cam_mask = np.zeros((299,299))  
mask = (cam[:, :, 2] < 30)  
cam_mask[mask] = 1  
plt.imshow(cam_mask)
```

```
[31]: <matplotlib.image.AxesImage at 0x7f867e085cc0>
```



```
[32]: # get lime mask for top 5 superpixels of actual label
explanation = explainer.explain_instance(image[0], model_InceptionV3.predict,
                                         num_samples = 500, labels = (argmax,), top_labels = None, random_seed = 42)
temp, lime_mask = explanation.get_image_and_mask(argmax, positive_only = True,
                                                 hide_rest = True)
boundaries = mark_boundaries(temp/2+.5, lime_mask)
plt.imshow(lime_mask)
print('Explanation score: ', explanation.score )
```

Explanation score: 0.5151263978355543



## 1.2 Compare Lime with bounding boxes

```
[38]: # get image with bounding box

path_to_xml = '/home/common_files/datasets/imagenet/bounding_boxes/n01484850/
↪n01484850_10798.xml'

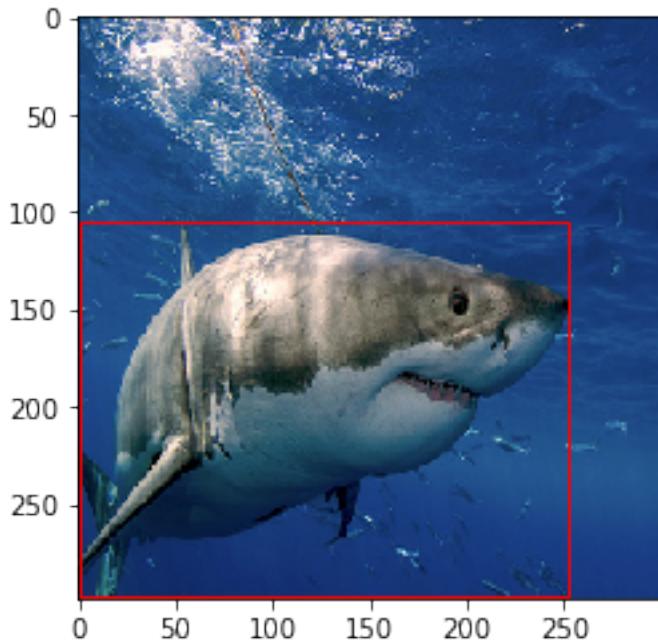
bounding_boxes = loadBoundingBoxes(path_to_xml,np.array(image_raw).shape[0],np.
↪array(image_raw).shape[1])

# Create rectangle patch
fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)
ax.imshow(np.array(image_raw))

for bounding_box in bounding_boxes:
    rect = patches.
    →Rectangle((bounding_box['xminScalled'],bounding_box['yminScalled']),bounding_box['xdiffScal
    ax.add_patch(rect)

plt.show()
```

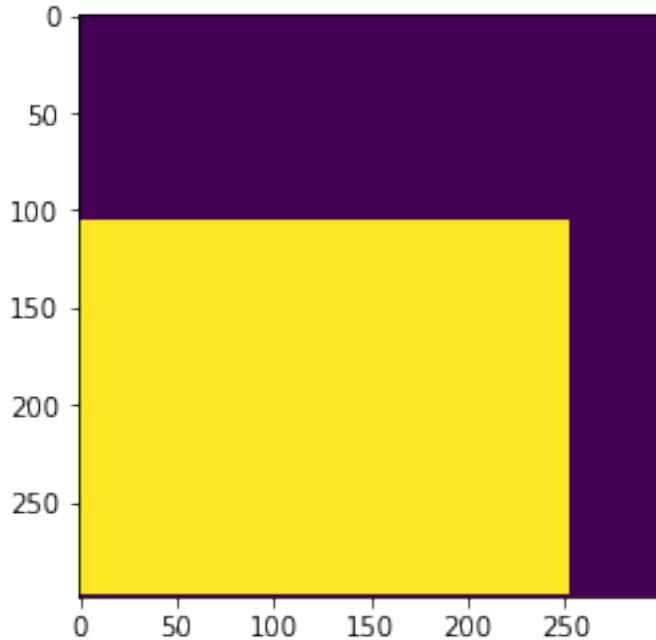
```
[{'xmin': 1, 'ymin': 118, 'xmax': 422, 'ymax': 332, 'xminScalled': 0,
'yminScalled': 105, 'xmaxScalled': 252, 'ymaxScalled': 298, 'xdiff': 421,
'ydif': 214, 'xdiffScalled': 252, 'ydifScalled': 193}]
```



```
[39]: # get mask for bounding box

bounding_box_mask = np.zeros((299,299))
for bounding_box in bounding_boxes:
    bounding_box_mask[bounding_box['yminScalled']:,
                      bounding_box['ymaxScalled'], bounding_box['xminScalled']:
                      bounding_box['xmaxScalled']] = 1
plt.imshow(bounding_box_mask)
```

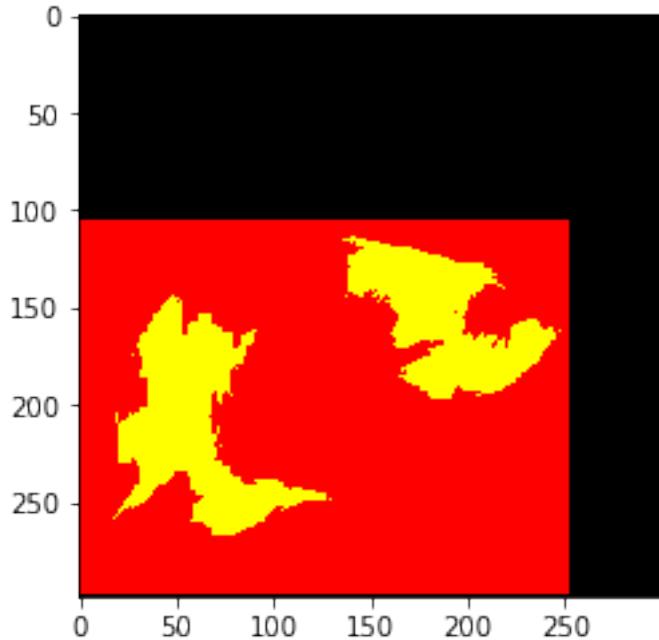
[39]: <matplotlib.image.AxesImage at 0x7f867df14dd8>



```
[40]: # compare masks: goal is to get intersection of both masks and see the  
→percentage of lime in bounding box
```

```
both_masks = np.zeros((299,299,3))  
both_masks[:, :, 0] = bounding_box_mask  
both_masks[:, :, 1] = lime_mask  
  
plt.imshow(both_masks)
```

```
[40]: <matplotlib.image.AxesImage at 0x7f867ded20f0>
```



```
[41]: pixel_both_masks = ((lime_mask+bounding_box_mask) == 2).sum()
pixel_lime_mask = (lime_mask == 1).sum() - pixel_both_masks
lime_in_bounding_box = pixel_both_masks / (pixel_lime_mask + pixel_both_masks)
print('Lime explanation in bounding box in %: ',lime_in_bounding_box * 100)
```

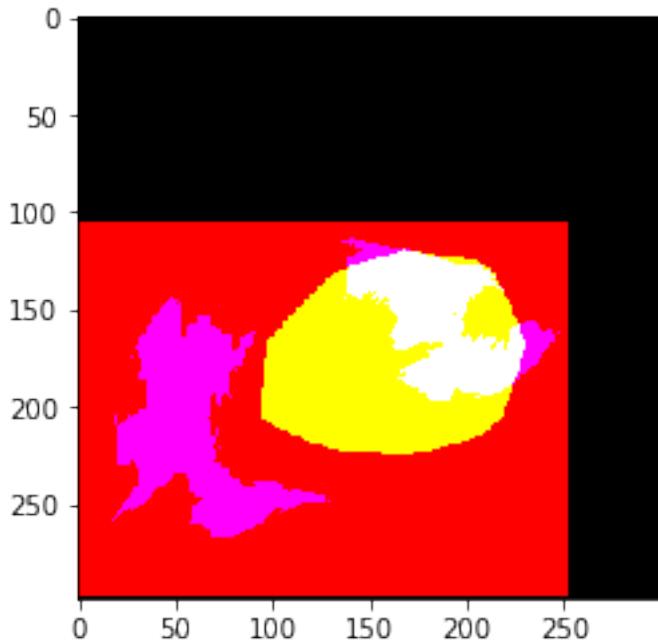
Lime explanation in bounding box in %: 100.0

### 1.3 Compare Class Activation Map with bounding boxes

```
[42]: both_masks = np.zeros((299,299,3))
both_masks[:, :, 0] = bounding_box_mask
both_masks[:, :, 1] = cam_mask
both_masks[:, :, 2] = lime_mask

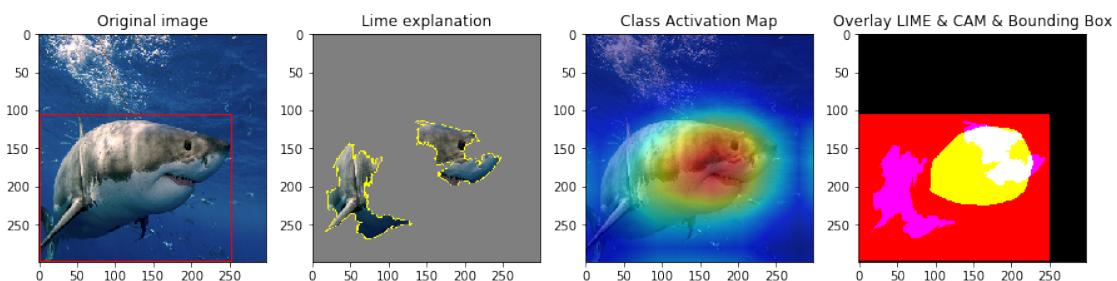
plt.imshow(both_masks)
```

```
[42]: <matplotlib.image.AxesImage at 0x7f867de417b8>
```



```
[43]: fig, ax = plt.subplots(1,4, figsize = (15,15))
ax[0].imshow(np.array(image_raw))

for bounding_box in bounding_boxes:
    rect = patches.Rectangle((bounding_box['xminScalled'],bounding_box['yminScalled']),bounding_box['xdiffScal']
    ax[0].add_patch(rect)
ax[0].set_title('Original image')
ax[1].imshow(boundaries)
ax[1].set_title('Lime explanation')
ax[2].imshow(overlay(np.array(image_raw),cam, alpha=0.5))
ax[2].set_title('Class Activation Map')
ax[3].imshow(both_masks)
ax[3].set_title('Overlay LIME & CAM & Bounding Box')
plt.show()
```



```
[44]: both_masks = np.zeros((299,299,3))
pixel_both_masks = ((cam_mask+bounding_box_mask) == 2).sum()
pixel_cam_mask = (cam_mask == 1).sum() - pixel_both_masks
cam_in_bounding_box = pixel_both_masks / (pixel_cam_mask + pixel_both_masks)
print('Class Activation Map in bounding box in %: ',cam_in_bounding_box * 100)
```

Class Activation Map in bounding box in %: 100.0

## 1.4 Approach to detect bias and weaknesses in training data of model systematically using Lime and Class Activation Maps

- We predicted 11 100 images using the InceptionV3 CNN and saved the results in a dataframe
- Dataframe contains masks of explanations, bounding boxes and predicted classes
- In total 222 classes, each 50 Samples

```
[45]: base_path = '/home/common_files/datasets/imagenet/bounding_boxes'
results_file = '/home/viscif/akif/mask_results.h5'
```

### Get class names of images

```
[46]: # Get class names of images
class_names = []
if os.path.isfile(results_file):
    with h5py.File(results_file, 'r') as hf:
        keys = hf.keys()
        #print(keys)
        for x in keys:
            class_names.append(x)
```

```
[47]: # get class names with indexes from imagenet json file and store as key value pairs
classJSON = "/home/viscif/.keras/models/imagenet_class_index.json"

with open(classJSON) as json_file:
    label_list = json.load(json_file)
    invers_label_list = {}
    for class_ID, value in label_list.items():
        invers_label_list[value[0]] = int(class_ID)

    # for example get label and label_name for image index 0
    label_list['0']
```

```
[47]: ['n01440764', 'tench']
```

#### 1.4.1 Get masks for Bounding Boxes and Class Activation Maps

```
[48]: def get_bounding_box_mask(bounding_boxes):
    bounding_box_mask = np.zeros((299,299))
    for bounding_box in bounding_boxes:
        bounding_box_mask[bounding_box['yminScalled']:
        →bounding_box['ymaxScalled'],bounding_box['xminScalled']:
        →bounding_box['xmaxScalled']] = 1
    return bounding_box_mask

[49]: def get_cam_mask(cam):
    cam_mask = np.zeros((cam.shape[0],cam.shape[1]))
    # get area where red channel is higher than 100
    mask = (cam[:, :, 0] > 100)
    cam_mask[mask] = 1
    return cam_mask
```

#### 1.4.2 Get size of intersection area between LIME and Bounding Boxes, CAM and Bounding Boxes, and its proportion in % for each image (sample)

```
[50]: # analyze row wise
def analyze_row(dataset_row):

    # get data
    file_name = dataset_row['filename']
    actual_image_class = dataset_row['imageClass']
    actual_image_class_index = dataset_row['imageClassID']
    actual_image_class_name = label_list['{}'.
    →format(actual_image_class_index)][1]
    cam_map = dataset_row['attentionMap']
    cam_mask = get_cam_mask(cam_map)
    lime_mask = dataset_row['LimeMask']
    bounding_box = dataset_row['boundingBoxes']
    bounding_box_mask = get_bounding_box_mask(bounding_box)
    predictions = dataset_row['prediction']
    predicted_image_class_index = np.argmax(predictions)
    predicted_image_class = label_list['{}'.
    →format(predicted_image_class_index)][0]
    predicted_image_class_name = label_list['{}'.
    →format(predicted_image_class_index)][1]

    # get rank of actual label in predictions
    y = predictions.argsort()
    rank = (len(y) - np.argwhere(y == actual_image_class_index))[0][0]

    # calculate total size of areas of masks
    area_bounding_box = ((bounding_box_mask) == 1).sum()
```

```

area_lime = ((lime_mask) == 1).sum()
area_cam = ((cam_mask) == 1).sum()

# get intersection between lime and bounding box
area_intersection_boundingbox_lime = ((bounding_box_mask + lime_mask) == 2).
→sum()

# get intersection between cam and bounding box
area_intersection_boundingbox_cam = ((bounding_box_mask + cam_mask) == 2).
→sum()

# get overlap in percentage
overlap_lime_bounding_box = max(area_intersection_boundingbox_lime /
→area_lime, area_intersection_boundingbox_lime / area_bounding_box)
overlap_cam_bounding_box = max(area_intersection_boundingbox_cam /
→area_cam, area_intersection_boundingbox_cam / area_bounding_box)

# lime explanation score
lime_explanation_score = dataset_row['lime_score']

data = {

    'file_name' : [file_name],
    'actual_image_class' : [actual_image_class],
    'actual_image_class_index' : [actual_image_class_index],
    'actual_image_class_name' : [actual_image_class_name],
    'predicted_image_class' : [predicted_image_class],
    'predicted_image_class_index' : [predicted_image_class_index],
    'predicted_image_class_name' : [predicted_image_class_name],
    'rank_of_actual_label_in_prediction' : [rank],
    'area_lime' : [area_lime],
    'area_cam' : [area_cam],
    'area_intersection_boundingbox_cam' : [
→[area_intersection_boundingbox_cam],
        'area_intersection_boundingbox_lime' : [
→[area_intersection_boundingbox_lime],
            'overlap_lime_bounding_box' : [overlap_lime_bounding_box],
            'overlap_cam_bounding_box' : [overlap_cam_bounding_box],
            'lime_explanation_score' : [lime_explanation_score],
    ]
}

return data

```

Load all results in a dataframe and a dictionary (key = class\_name: value = data)

```
[51]: all_results_dict = {}
all_results_df = pd.DataFrame()
for class_name in class_names:

    class_results = pd.DataFrame()
    dataset = pd.read_hdf(results_file, key = class_name)

    for i in range(len(dataset)):
        row = dataset.iloc[i]

        data = analyze_row(row)
        class_results = class_results.append(pd.DataFrame(data), ignore_index = False)
    all_results_df = all_results_df.append(pd.DataFrame(data), ignore_index=True)

all_results_dict.update({class_name : class_results})
```

### Dictionary with all results of images stored by key = actual\_image\_class

```
[52]: all_results_dict['n01443537'].head(5)
```

	file_name	actual_image_class	actual_image_class_index	\
0	n01443537_15077.jpg	n01443537		1
1	n01443537_3770.jpg	n01443537		1
2	n01443537_14753.jpg	n01443537		1
3	n01443537_15164.jpg	n01443537		1
4	n01443537_17158.jpg	n01443537		1

	actual_image_class_name	predicted_image_class	predicted_image_class_index	\
0	goldfish	n01440764		0
1	goldfish	n01443537		1
2	goldfish	n01443537		1
3	goldfish	n01443537		1
4	goldfish	n01443537		1

	predicted_image_class_name	rank_of_actual_label_in_prediction	area_lime	\
0	tench	2	4764	
1	goldfish	1	9167	
2	goldfish	1	10706	
3	goldfish	1	7263	
4	goldfish	1	10899	

	area_cam	area_intersection_boundingbox_cam	\
0	8064	8064	
1	21189	19553	

```

2      23889                      21674
3      25074                      24831
4      14215                      14215

      area_intersection_boundingbox_lime  overlap_lime_bounding_box \
0                          1692          0.355164
1                          9167          1.000000
2                         10131          0.946292
3                          7151          0.984579
4                          9345          0.857418

      overlap_cam_bounding_box  lime_explanation_score
0           1.000000          0.754628
1           0.922790          0.866595
2           0.907280          0.695441
3           0.990309          0.817954
4           1.000000          0.685793

```

### Dataframe with all results of images

[53]: `all_results_df.head(5)`

```

[53]:   file_name actual_image_class  actual_image_class_index \
0  n01443537_15077.jpg        n01443537                      1
1  n01443537_3770.jpg        n01443537                      1
2  n01443537_14753.jpg        n01443537                      1
3  n01443537_15164.jpg        n01443537                      1
4  n01443537_17158.jpg        n01443537                      1

      actual_image_class_name predicted_image_class  predicted_image_class_index \
0            goldfish          n01440764                      0
1            goldfish          n01443537                      1
2            goldfish          n01443537                      1
3            goldfish          n01443537                      1
4            goldfish          n01443537                      1

      predicted_image_class_name  rank_of_actual_label_in_prediction  area_lime \
0                  tench                           2                 4764
1            goldfish                           1                 9167
2            goldfish                           1                10706
3            goldfish                           1                 7263
4            goldfish                           1                10899

      area_cam  area_intersection_boundingbox_cam \
0      8064          8064
1     21189          19553
2     23889          21674
3     25074          24831

```

```

4      14215          14215

    area_intersection_boundingbox_lime  overlap_lime_bounding_box \
0                  1692            0.355164
1                  9167            1.000000
2                 10131            0.946292
3                  7151            0.984579
4                  9345            0.857418

    overlap_cam_bounding_box  lime_explanation_score
0           1.000000        0.754628
1           0.922790        0.866595
2           0.907280        0.695441
3           0.990309        0.817954
4           1.000000        0.685793

```

### Get statistics for all images in dataframe

[54]: `all_results_df.describe()`

```

[54]:      actual_image_class_index  predicted_image_class_index \
count          11100.000000        11100.000000
mean          483.648649        484.727477
std           283.801093        284.420150
min           1.000000         0.000000
25%          237.000000        237.000000
50%          486.500000        489.000000
75%          733.000000        733.000000
max          999.000000        999.000000

      rank_of_actual_label_in_prediction  area_lime  area_cam \
count          11100.000000  11100.000000  11100.000000
mean          1.473874   10124.092342  22194.892342
std           7.121318   3298.999635  10844.926638
min           1.000000   2400.000000     0.000000
25%          1.000000   7767.500000  14807.500000
50%          1.000000   9694.500000  19762.500000
75%          1.000000  12028.000000  27404.750000
max          420.000000  28845.000000  81219.000000

      area_intersection_boundingbox_cam  area_intersection_boundingbox_lime \
count          11100.000000        11100.000000
mean          16187.004595        7254.651622
std           11250.360534        3985.937306
min           0.000000         0.000000
25%          8277.000000        4410.750000
50%          14866.000000       7062.500000
75%          21981.000000       9818.000000

```

```

max                      78912.000000
                           27706.000000

      overlap_lime_bounding_box  overlap_cam_bounding_box \
count          11100.000000           11093.000000
mean           0.740144            0.799245
std            0.253294            0.269324
min            0.000000            0.000000
25%           0.585225            0.729364
50%           0.808860            0.910648
75%           0.965548            0.989468
max           1.000000            1.000000

      lime_explanation_score
count          11100.000000
mean           0.832392
std            0.083350
min            0.173414
25%           0.790363
50%           0.847984
75%           0.890675
max           0.992284

```

### Get correlation

[55]: all\_results\_df.corr()

	actual_image_class_index \
actual_image_class_index	1.000000
predicted_image_class_index	0.969502
rank_of_actual_label_in_prediction	0.023830
area_lime	0.025868
area_cam	0.158984
area_intersection_boundingbox_cam	0.030454
area_intersection_boundingbox_lime	-0.106007
overlap_lime_bounding_box	-0.136302
overlap_cam_bounding_box	-0.089448
lime_explanation_score	-0.099630

	predicted_image_class_index \
actual_image_class_index	0.969502
predicted_image_class_index	1.000000
rank_of_actual_label_in_prediction	0.016658
area_lime	0.024409
area_cam	0.149353
area_intersection_boundingbox_cam	0.024698
area_intersection_boundingbox_lime	-0.107839
overlap_lime_bounding_box	-0.135871
overlap_cam_bounding_box	-0.094904

lime_explanation_score	-0.103194
actual_image_class_index	rank_of_actual_label_in_prediction \ 0.023830
predicted_image_class_index	0.016658
rank_of_actual_label_in_prediction	1.000000
area_lime	-0.022699
area_cam	-0.054065
area_intersection_boundingbox_cam	-0.069720
area_intersection_boundingbox_lime	-0.052473
overlap_lime_bounding_box	-0.061117
overlap_cam_bounding_box	-0.103071
lime_explanation_score	-0.061750
	area_lime area_cam \
actual_image_class_index	0.025868 0.158984
predicted_image_class_index	0.024409 0.149353
rank_of_actual_label_in_prediction	-0.022699 -0.054065
area_lime	1.000000 0.093452
area_cam	0.093452 1.000000
area_intersection_boundingbox_cam	0.130716 0.731747
area_intersection_boundingbox_lime	0.653848 0.179760
overlap_lime_bounding_box	0.110180 0.166410
overlap_cam_bounding_box	0.077209 0.190041
lime_explanation_score	-0.058426 -0.024667
	area_intersection_boundingbox_cam \
actual_image_class_index	0.030454
predicted_image_class_index	0.024698
rank_of_actual_label_in_prediction	-0.069720
area_lime	0.130716
area_cam	0.731747
area_intersection_boundingbox_cam	1.000000
area_intersection_boundingbox_lime	0.500874
overlap_lime_bounding_box	0.507187
overlap_cam_bounding_box	0.517551
lime_explanation_score	-0.061575
	area_intersection_boundingbox_lime \
actual_image_class_index	-0.106007
predicted_image_class_index	-0.107839
rank_of_actual_label_in_prediction	-0.052473
area_lime	0.653848
area_cam	0.179760
area_intersection_boundingbox_cam	0.500874
area_intersection_boundingbox_lime	1.000000
overlap_lime_bounding_box	0.714436

```

overlap_cam_bounding_box          0.329493
lime_explanation_score           -0.016460

                                overlap_lime_bounding_box \
actual_image_class_index         -0.136302
predicted_image_class_index      -0.135871
rank_of_actual_label_in_prediction -0.061117
area_lime                         0.110180
area_cam                          0.166410
area_intersection_boundingbox_cam 0.507187
area_intersection_boundingbox_lime 0.714436
overlap_lime_bounding_box        1.000000
overlap_cam_bounding_box         0.411369
lime_explanation_score           0.065325

                                overlap_cam_bounding_box \
actual_image_class_index         -0.089448
predicted_image_class_index      -0.094904
rank_of_actual_label_in_prediction -0.103071
area_lime                         0.077209
area_cam                          0.190041
area_intersection_boundingbox_cam 0.517551
area_intersection_boundingbox_lime 0.329493
overlap_lime_bounding_box        0.411369
overlap_cam_bounding_box         1.000000
lime_explanation_score           0.006835

                                lime_explanation_score
actual_image_class_index         -0.099630
predicted_image_class_index      -0.103194
rank_of_actual_label_in_prediction -0.061750
area_lime                         -0.058426
area_cam                          -0.024667
area_intersection_boundingbox_cam -0.061575
area_intersection_boundingbox_lime -0.016460
overlap_lime_bounding_box        0.065325
overlap_cam_bounding_box         0.006835
lime_explanation_score           1.000000

```

#### 1.4.3 Get statistics for each image class

```
[56]: # get statistics class wise

def get_statistics_for_classes(class_name):
    #print('class_name: ', class_name)
```

```

    min_overlap_lime_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_lime_bounding_box'].min()
    mean_overlap_lime_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_lime_bounding_box'].mean()
    max_overlap_lime_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_lime_bounding_box'].max()
    std_overlap_lime_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_lime_bounding_box'].std()

    min_lime_explanation_score =_
    ↪all_results_dict[class_name]['lime_explanation_score'].min()
    mean_lime_explanation_score =_
    ↪all_results_dict[class_name]['lime_explanation_score'].mean()
    max_lime_explanation_score =_
    ↪all_results_dict[class_name]['lime_explanation_score'].max()
    std_lime_explanation_score =_
    ↪all_results_dict[class_name]['lime_explanation_score'].std()
    corr_lime_exp_score_overlap =_
    ↪all_results_dict[class_name]['lime_explanation_score'].
    ↪corr(all_results_dict[class_name]['overlap_lime_bounding_box'])

    min_overlap_cam_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_cam_bounding_box'].min()
    mean_overlap_cam_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_cam_bounding_box'].mean()
    max_overlap_cam_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_cam_bounding_box'].max()
    std_overlap_cam_bb_percentage =_
    ↪all_results_dict[class_name]['overlap_cam_bounding_box'].std()

# get accuracy for class
true = all_results_dict[class_name]['rank_of_actual_label_in_prediction'].
↪where((all_results_dict[class_name]['rank_of_actual_label_in_prediction'] ==_
↪1)).count()
class_accuracy = true /_
↪all_results_dict[class_name]['rank_of_actual_label_in_prediction'].count()

data = {
    'class_name' : [class_name],
    'class_accuracy' : [class_accuracy],
    'min_overlap_lime_bb_percentage' : [min_overlap_lime_bb_percentage],
    'mean_overlap_lime_bb_percentage' : [mean_overlap_lime_bb_percentage],
    'max_overlap_lime_bb_percentage' : [max_overlap_lime_bb_percentage],
    'std_overlap_lime_bb_percentage' : [std_overlap_lime_bb_percentage],  

    'min_lime_explanation_score' : [min_lime_explanation_score],  

    'corr_lime_exp_score_overlap' : [corr_lime_exp_score_overlap],  

    'min_overlap_cam_bb_percentage' : [min_overlap_cam_bb_percentage],
    'mean_overlap_cam_bb_percentage' : [mean_overlap_cam_bb_percentage],
    'max_overlap_cam_bb_percentage' : [max_overlap_cam_bb_percentage],
    'std_overlap_cam_bb_percentage' : [std_overlap_cam_bb_percentage]
}

```

```

        'mean_lime_explanation_score' : [mean_lime_explanation_score],
        'max_lime_explanation_score' : [max_lime_explanation_score],
        'std_lime_explanation_score' : [std_lime_explanation_score],
        'corr_lime_exp_score_overlap' : [corr_lime_exp_score_overlap],

        'min_overlap_cam_bb_percentage' : [min_overlap_cam_bb_percentage],
        'mean_overlap_cam_bb_percentage' : [mean_overlap_cam_bb_percentage],
        'max_overlap_cam_bb_percentage' : [max_overlap_cam_bb_percentage],
        'std_overlap_cam_bb_percentage' : [std_overlap_cam_bb_percentage]

    }

    return data

```

[57]: statistics\_class\_data = pd.DataFrame()

```

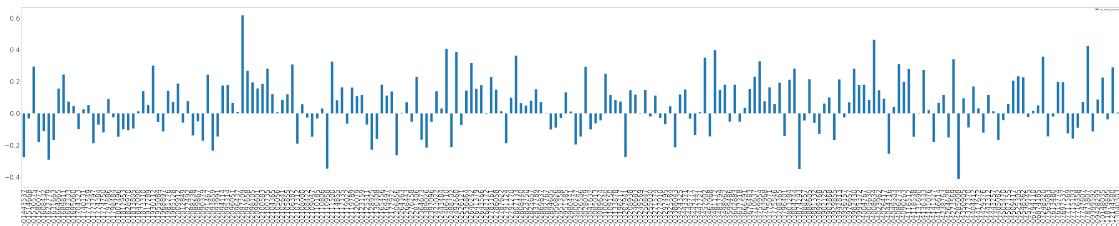
for class_name in class_names:
    statistics = get_statistics_for_classes(class_name)
    statistics_class_data = statistics_class_data.append(pd.
→DataFrame(statistics), ignore_index = True)

```

### Show correlation between lime explanation score and the overlap of lime and bounding boxes

[58]: statistics\_class\_data.plot(kind='bar', x= 'class\_name', y =['corr\_lime\_exp\_score\_overlap'], figsize = (120,20), fontsize = 40)

[58]: <matplotlib.axes.\_subplots.AxesSubplot at 0x7f867e288320>



[59]: statistics\_class\_data[(statistics\_class\_data['mean\_overlap\_lime\_bb\_percentage'] < 0.55)]

	class_name	class_accuracy	min_overlap_lime_bb_percentage
95	n02786058	0.78	0.000000
99	n02807133	0.96	0.000000
125	n03250847	0.80	0.000000
145	n03666591	0.92	0.099350
146	n03676483	0.82	0.000000
147	n03710637	0.36	0.031049
155	n03804744	0.92	0.000000

164	n03942813	0.90	0.000000
166	n03976657	0.70	0.095323
175	n04049303	0.92	0.000000
178	n04116512	0.86	0.000000
179	n04118538	0.94	0.000000
181	n04136333	0.86	0.000000
186	n04264628	0.60	0.000000
199	n04509417	0.90	0.076389
208	n07615774	0.92	0.000000
217	n10148035	0.96	0.000000
95	mean_overlap_lime_bb_percentage	0.455146	0.959571
99	max_overlap_lime_bb_percentage	0.515116	0.946754
125		0.512461	1.000000
145		0.510497	1.000000
146		0.539601	1.000000
147		0.427715	0.993805
155		0.479744	1.000000
164		0.547116	1.000000
166		0.481183	1.000000
175		0.510640	0.998667
178		0.403676	0.952846
179		0.510663	1.000000
181		0.500953	0.996732
186		0.259097	0.964103
199		0.519033	0.964440
208		0.494803	0.996554
217		0.529918	0.995897
95	std_overlap_lime_bb_percentage	0.262416	0.558437
99	min_lime_explanation_score	0.283383	0.543017
125		0.267173	0.653652
145		0.222811	0.506809
146		0.272468	0.462748
147		0.226262	0.681668
155		0.308172	0.561971
164		0.338883	0.526728
166		0.249255	0.707665
175		0.275320	0.671591
178		0.307975	0.560490
179		0.328016	0.596861
181		0.231501	0.595153
186		0.283315	0.705642
199		0.223312	0.615868
208		0.314992	0.536259

217	0.257682	0.550633
	mean_lime_explanation_score	max_lime_explanation_score \
95	0.798119	0.947659
99	0.788100	0.979054
125	0.843100	0.982084
145	0.816477	0.986032
146	0.806826	0.945425
147	0.828558	0.914571
155	0.857881	0.952357
164	0.836150	0.991495
166	0.837414	0.929576
175	0.827143	0.955392
178	0.844554	0.989232
179	0.853204	0.955511
181	0.833821	0.985546
186	0.860512	0.946028
199	0.845725	0.984040
208	0.798251	0.976257
217	0.819787	0.916016
	std_lime_explanation_score	corr_lime_exp_score_overlap \
95	0.092930	0.149451
99	0.110215	0.362768
125	0.073166	0.147173
145	0.083523	0.035090
146	0.095942	0.153952
147	0.056866	0.230470
155	0.075261	0.281918
164	0.091756	0.213543
166	0.061386	0.070395
175	0.073205	0.041043
178	0.079575	0.279253
179	0.069854	-0.146489
181	0.073004	0.272977
186	0.049145	-0.151260
199	0.091871	0.205400
208	0.094816	0.198483
217	0.079532	0.225358
	min_overlap_cam_bb_percentage	mean_overlap_cam_bb_percentage \
95	0.000000	0.530757
99	0.000000	0.808150
125	0.000000	0.554436
145	0.000000	0.514472
146	0.000000	0.573999
147	0.000000	0.490610

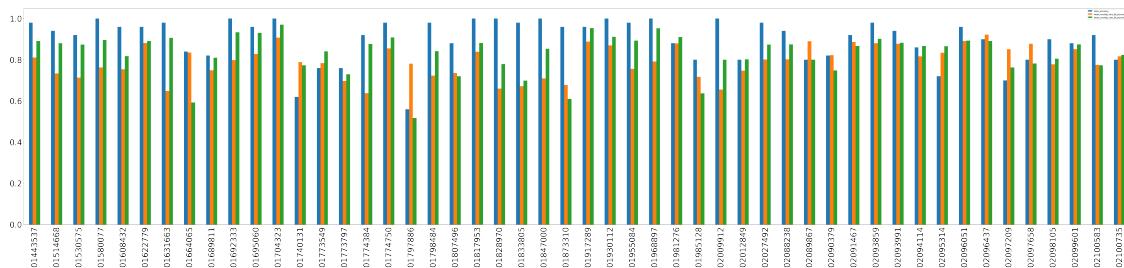
155	0.000000	0.790754
164	0.000000	0.725306
166	0.000000	0.571454
175	0.065703	0.799501
178	0.000000	0.640555
179	0.000000	0.692619
181	0.000000	0.638098
186	0.000000	0.283092
199	0.000000	0.794801
208	0.000000	0.610797
217	0.117438	0.603897

	max_overlap_cam_bb_percentage	std_overlap_cam_bb_percentage
95	1.000000	0.415437
99	1.000000	0.232908
125	1.000000	0.340591
145	1.000000	0.341318
146	1.000000	0.347946
147	1.000000	0.368954
155	1.000000	0.232995
164	1.000000	0.411250
166	1.000000	0.323712
175	1.000000	0.217841
178	1.000000	0.382576
179	1.000000	0.401407
181	1.000000	0.322861
186	1.000000	0.394010
199	1.000000	0.285458
208	1.000000	0.387190
217	0.961177	0.228498

Plot ratio between Accuracy (blue), LIME overlap (yellow) and CAM overlap (green) for each image class

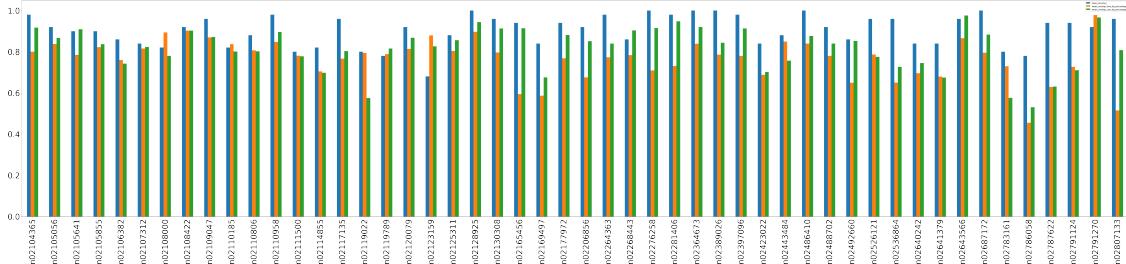
```
[60]: statistics_class_data[0:50].plot(kind='bar', x= 'class_name', y =  
    ['class_accuracy', 'mean_overlap_lime_bb_percentage',  
     'mean_overlap_cam_bb_percentage'], figsize = (100,20), fontsize = 40)
```

[60]: <matplotlib.axes.\_subplots.AxesSubplot at 0x7f867e50fef0>



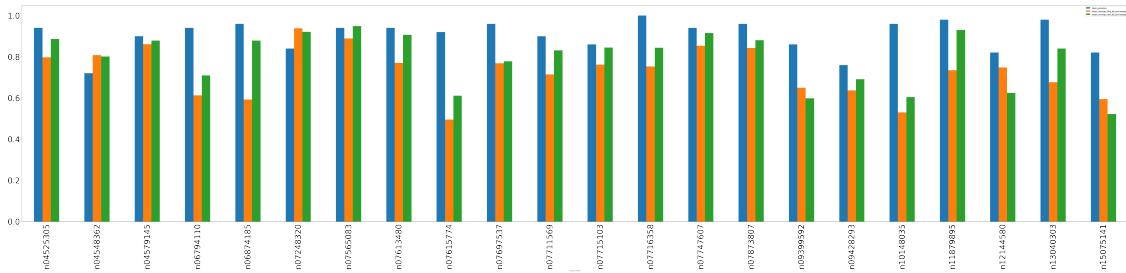
```
[61]: statistics_class_data[50:100].plot(kind='bar',x= 'class_name', y =_
    ['class_accuracy', 'mean_overlap_lime_bb_percentage',_
    'mean_overlap_cam_bb_percentage'], figsize = (100,20), fontsize = 40 )
```

[61]: <matplotlib.axes.\_subplots.AxesSubplot at 0x7f867e4e2e10>



```
[64]: statistics_class_data[200:].plot(kind='bar',x= 'class_name', y = [
    'class_accuracy', 'mean_overlap_lime_bb_percentage',
    'mean_overlap_cam_bb_percentage'], figsize = (100,20), fontsize = 40)
```

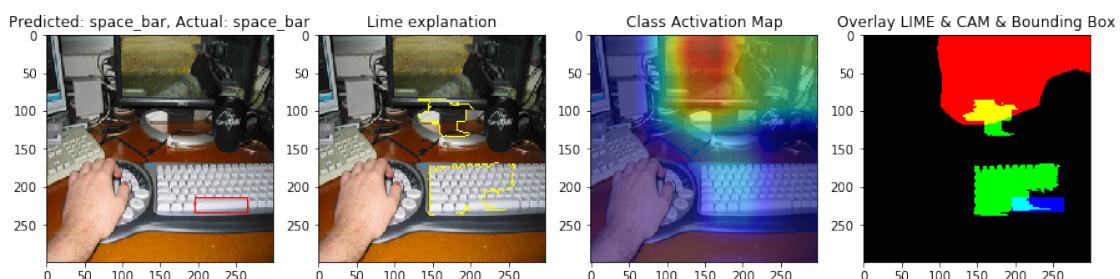
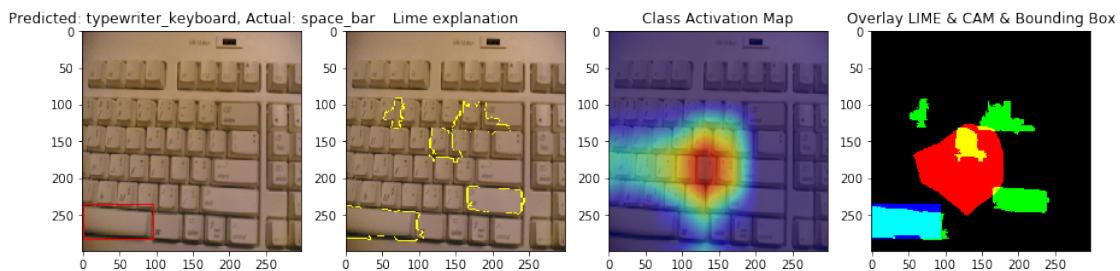
```
[64]: <matplotlib.axes._subplots.AxesSubplot at 0x7f867ef10ac8>
```

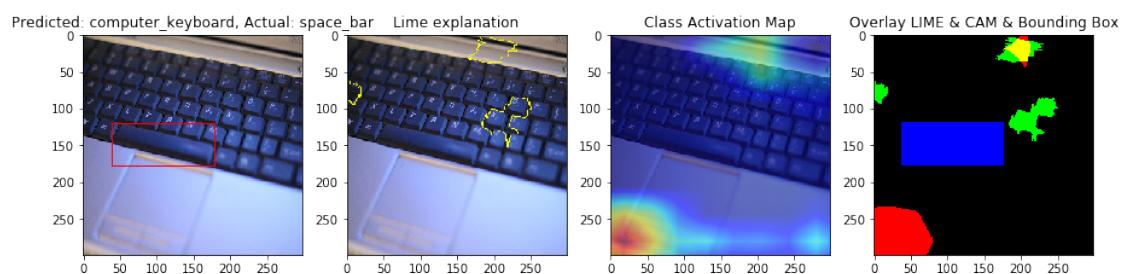
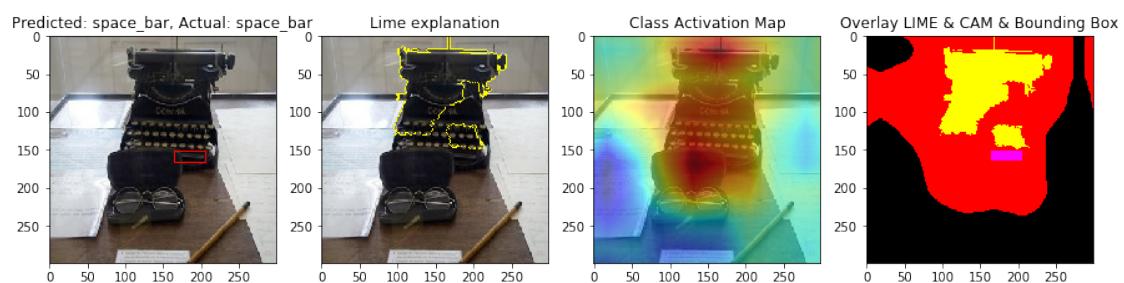
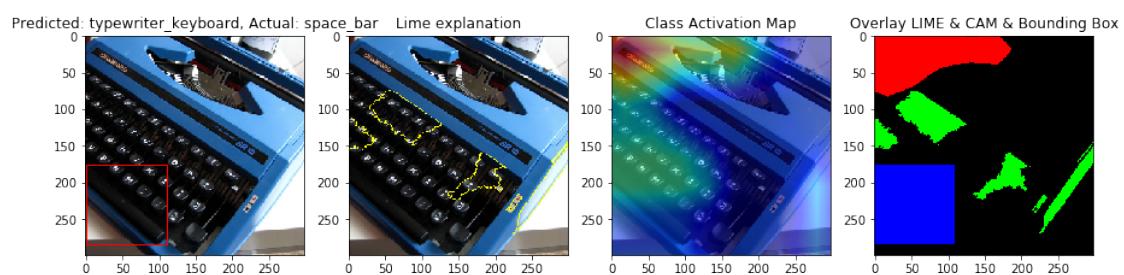
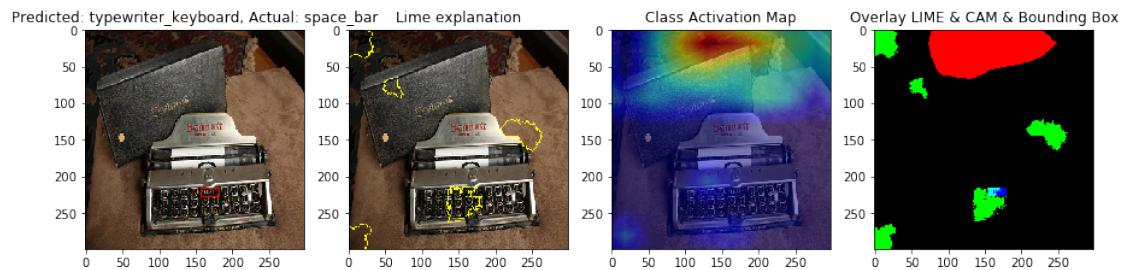


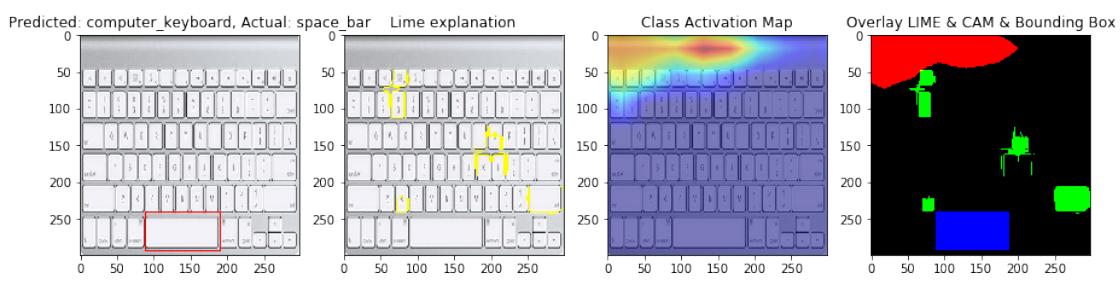
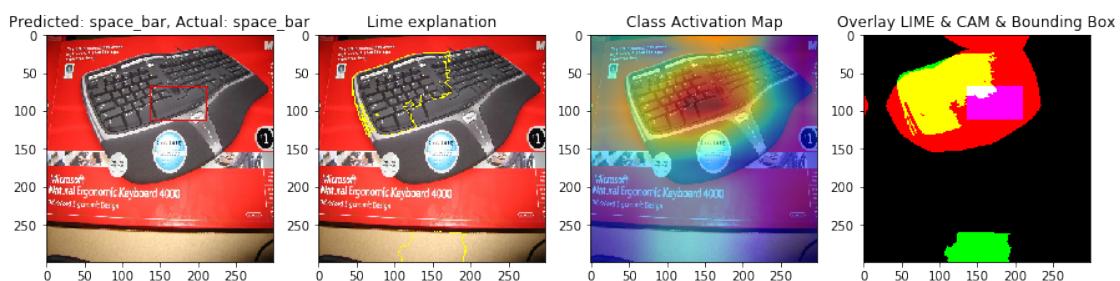
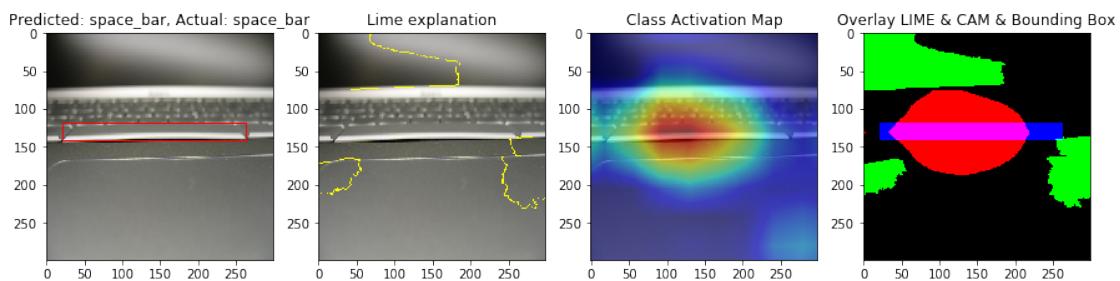
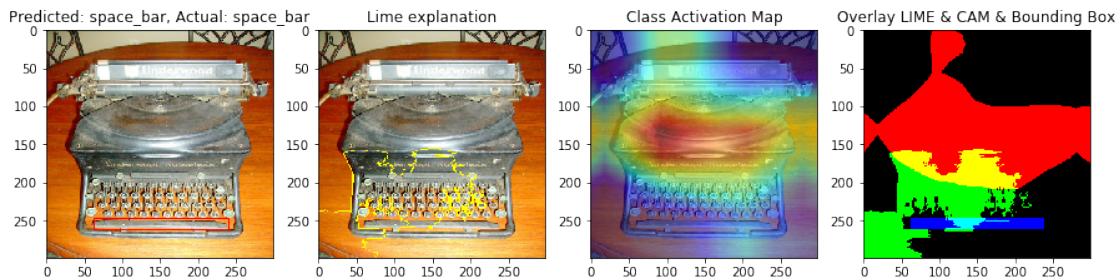
#### 1.4.4 Plot showy image classes observed from plots

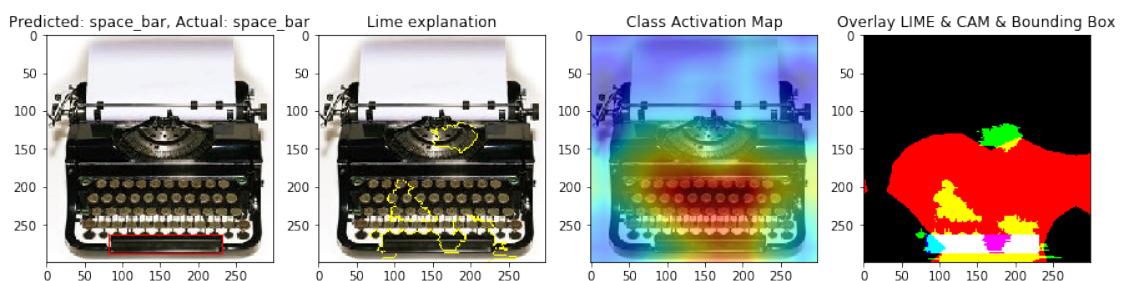
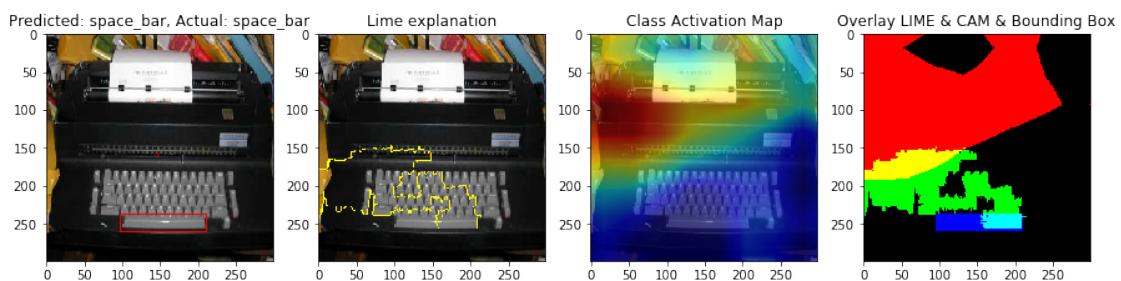
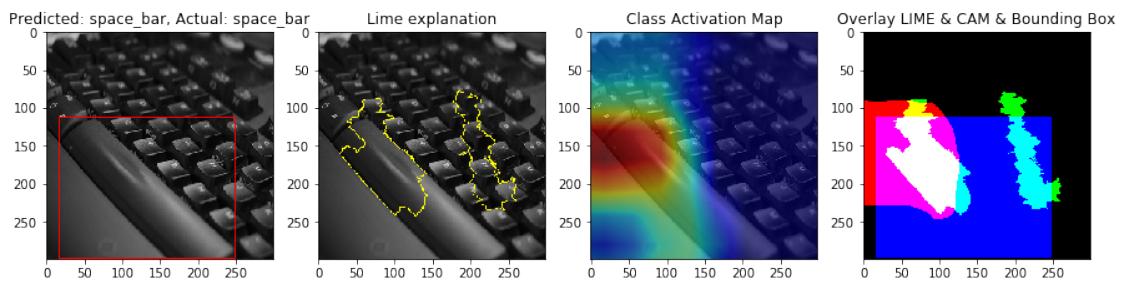
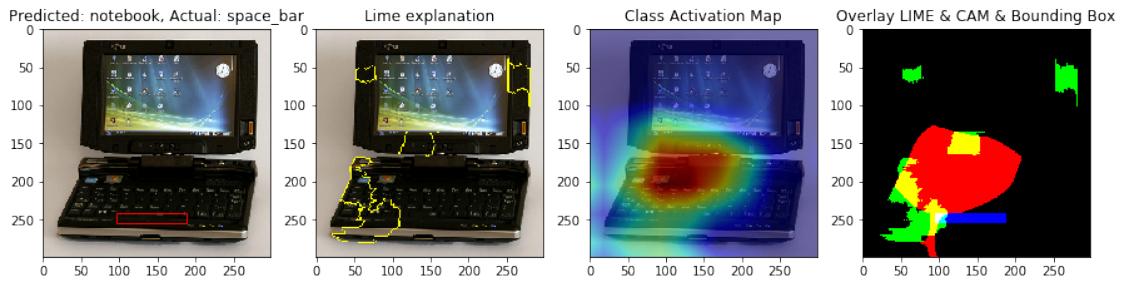
```
[65]: class_data = pd.read_hdf(results_file, key = 'n04264628')

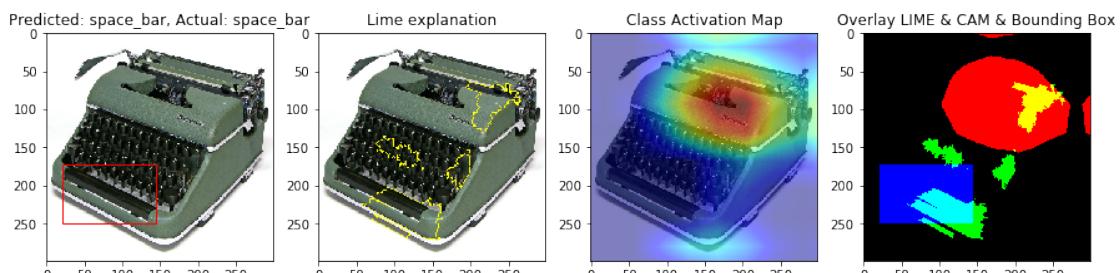
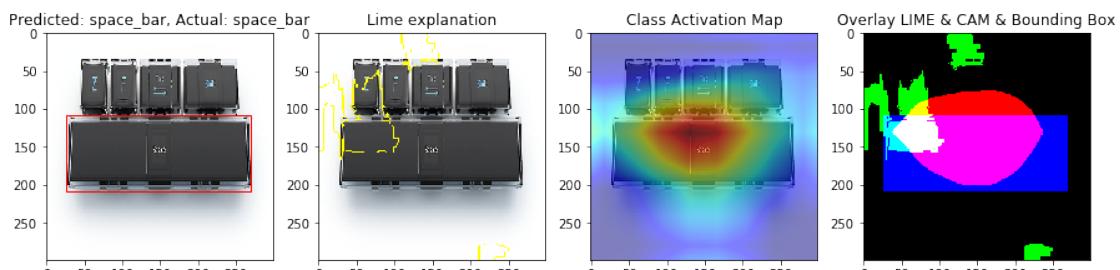
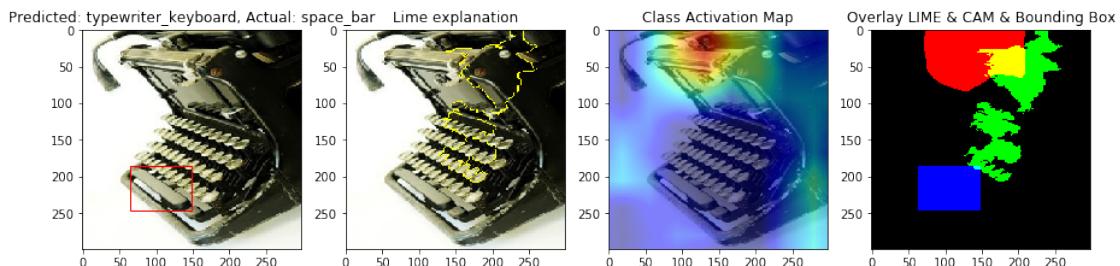
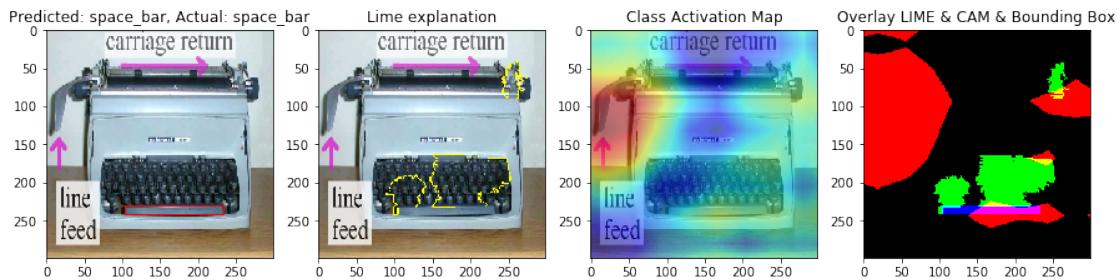
for i in range(len(class_data)):
    row = class_data.iloc[i]
    print_row(row)
```

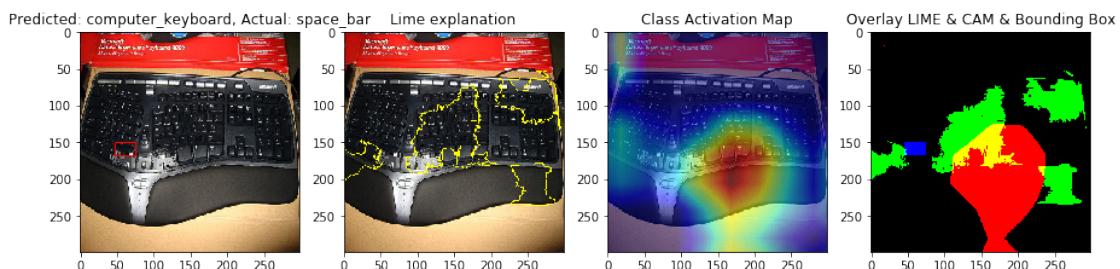
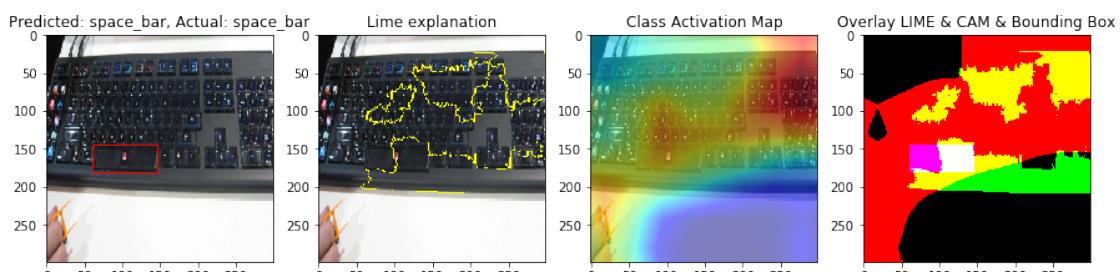
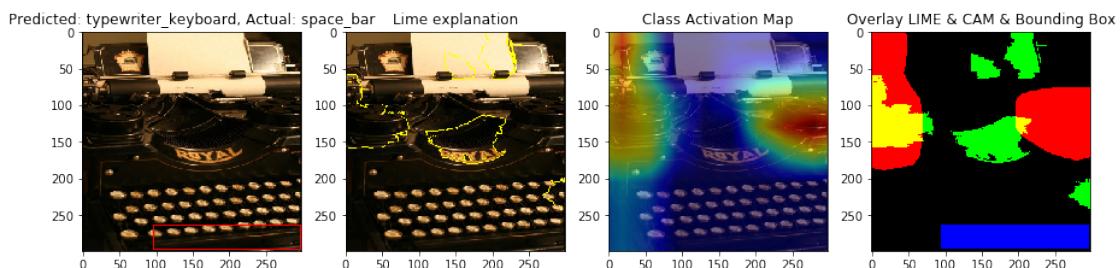
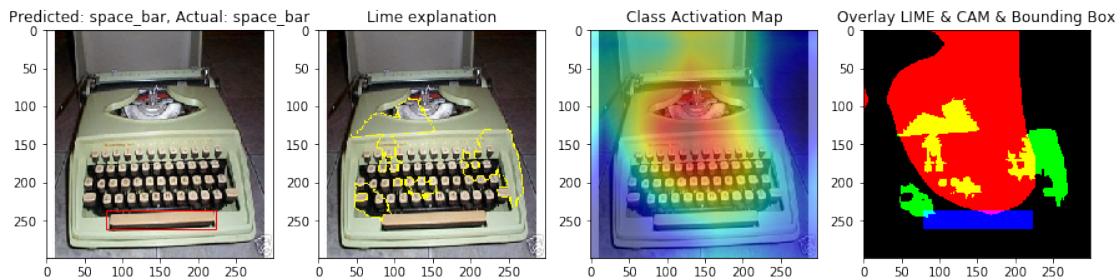


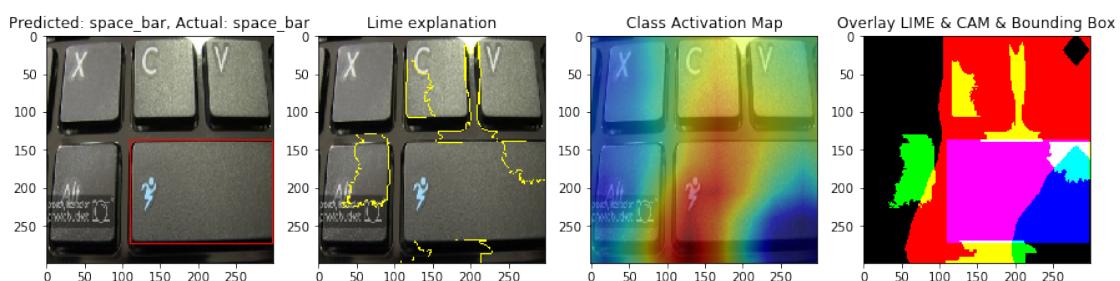
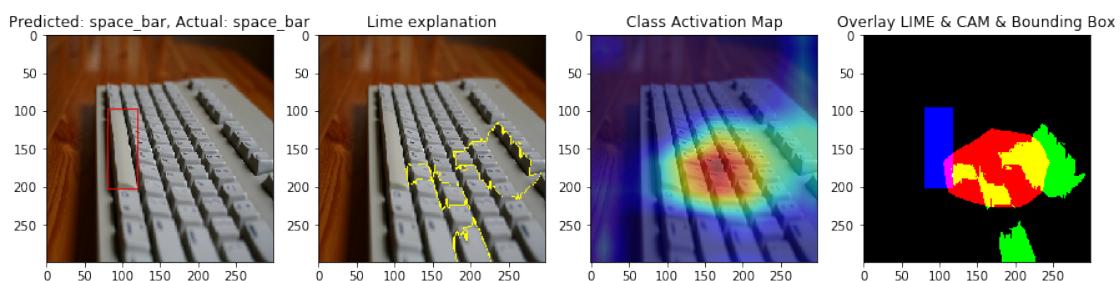
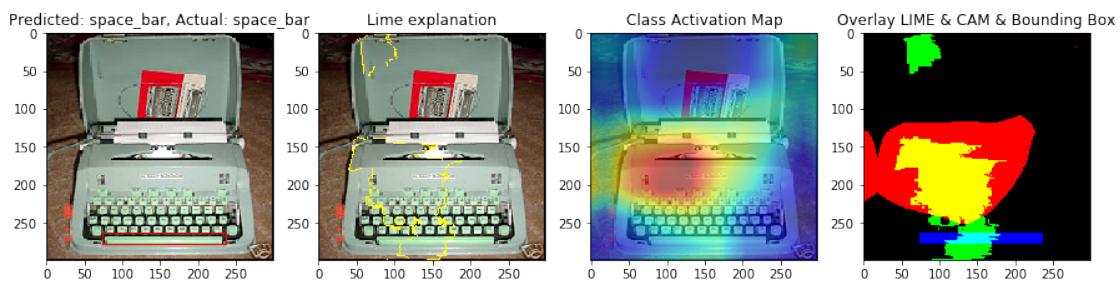
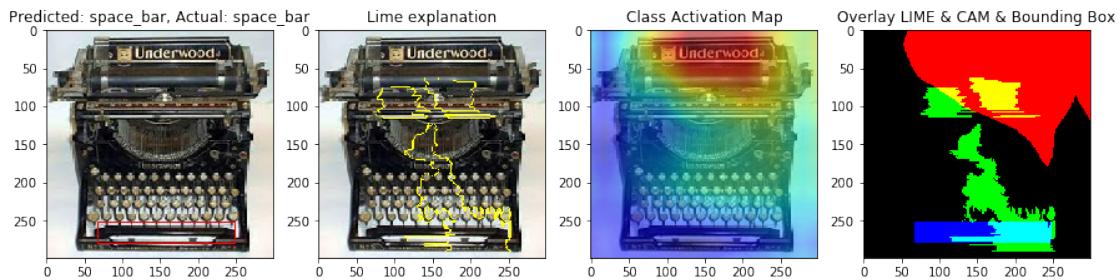


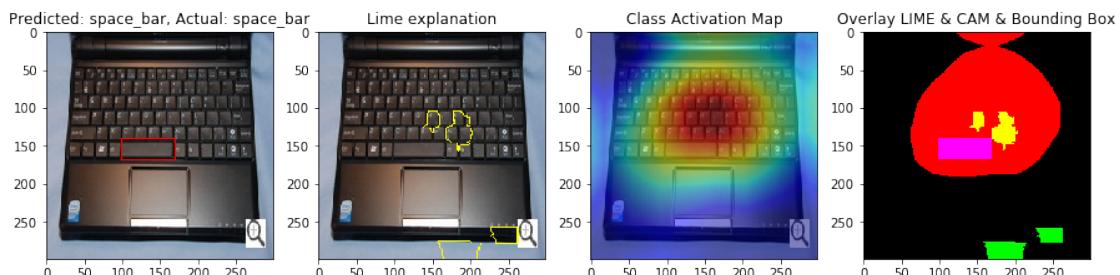
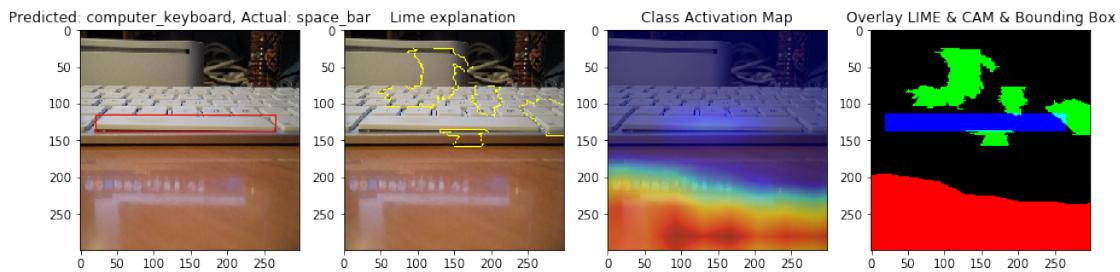
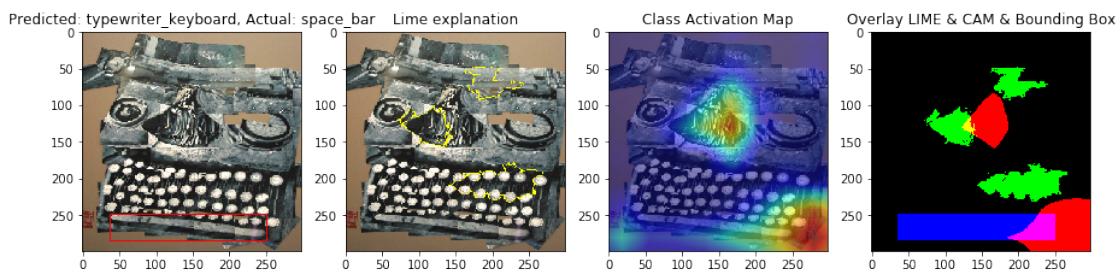
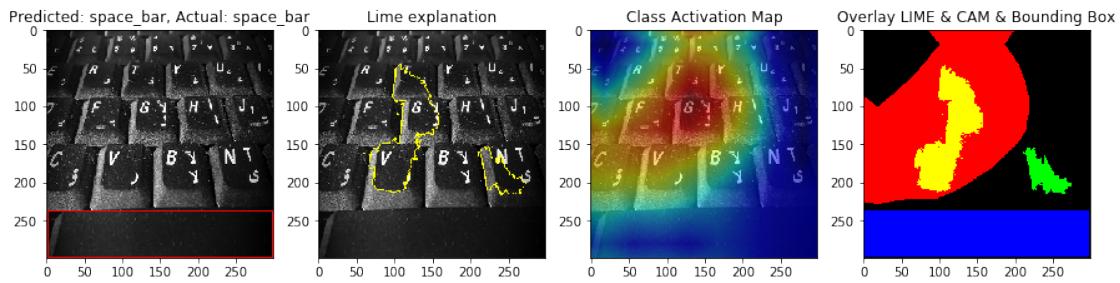


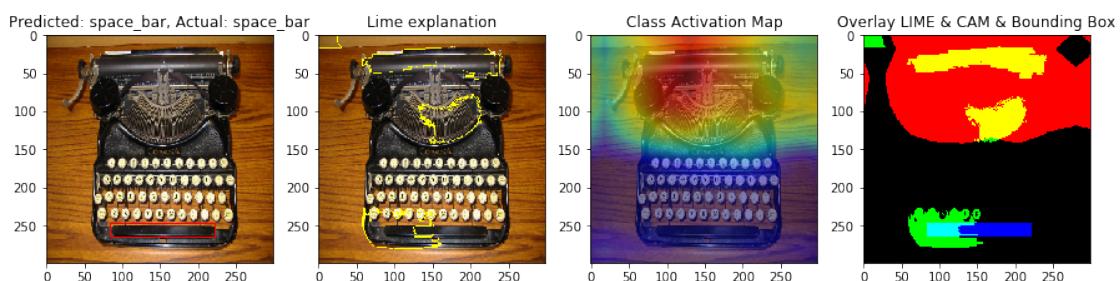
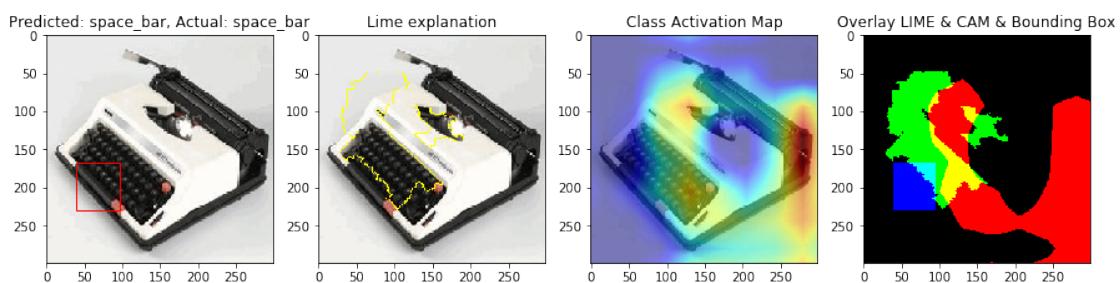
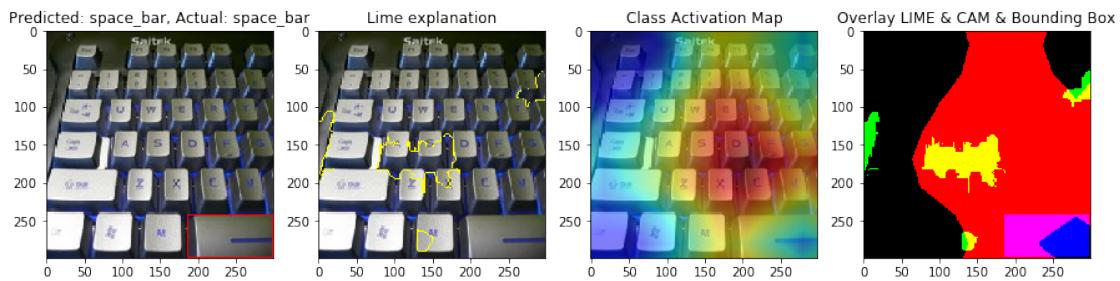
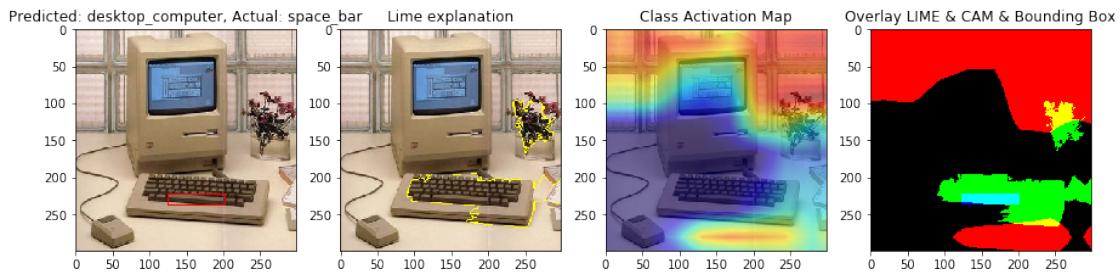


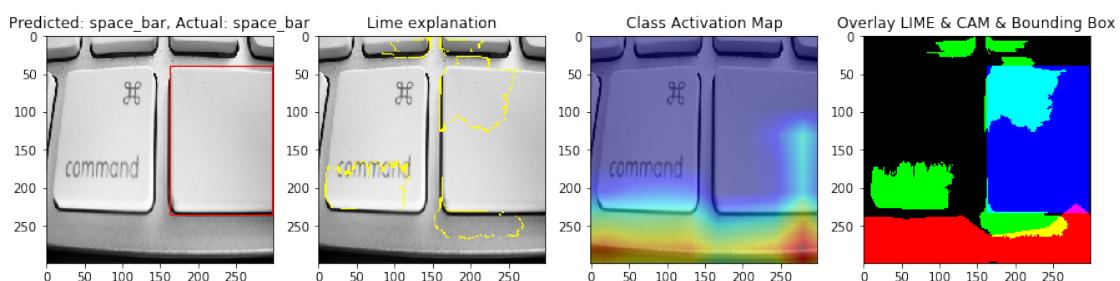
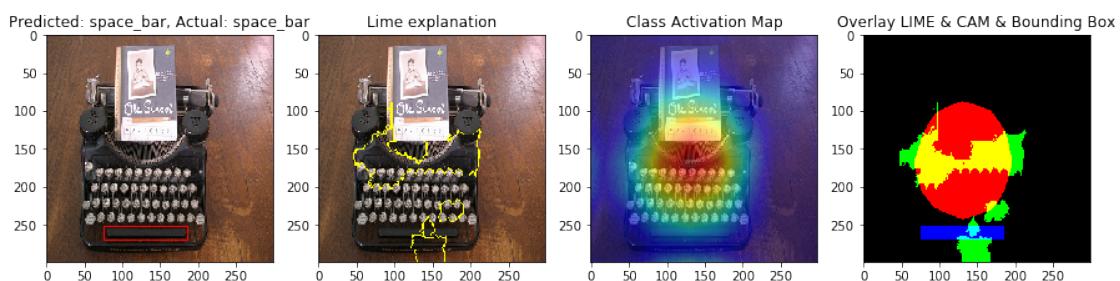
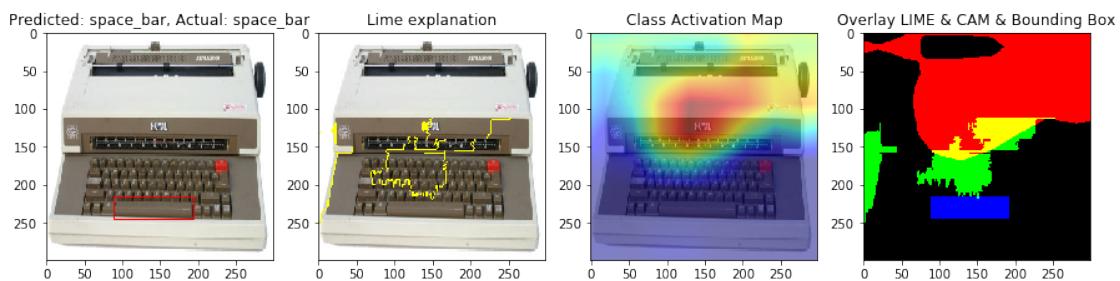
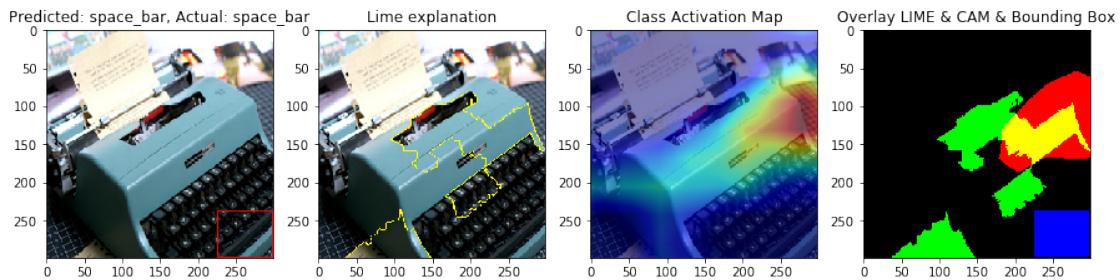


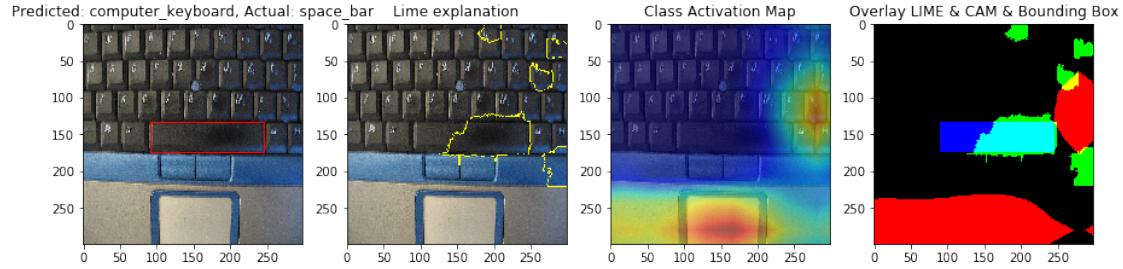
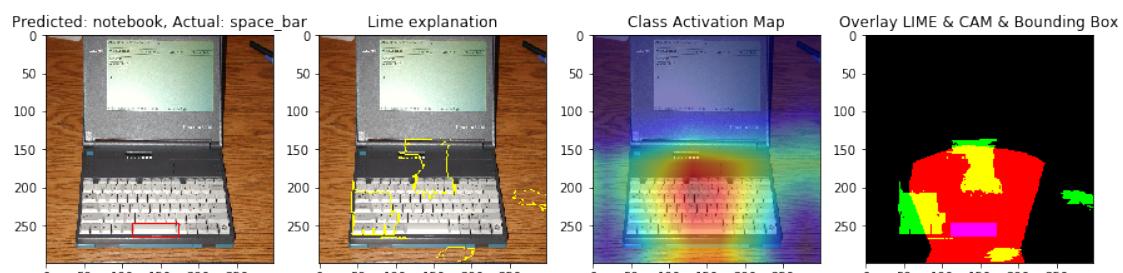
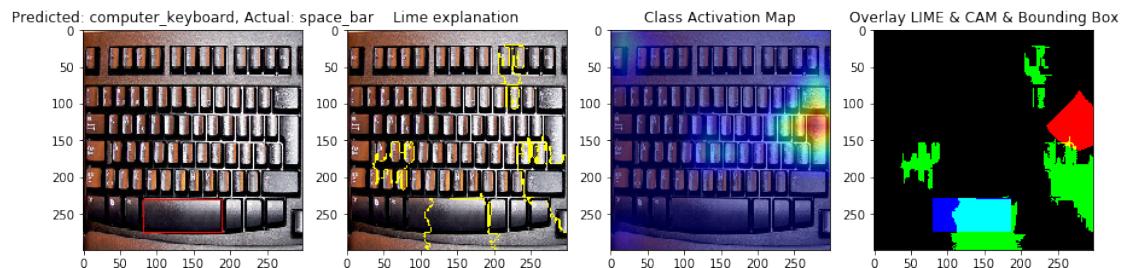
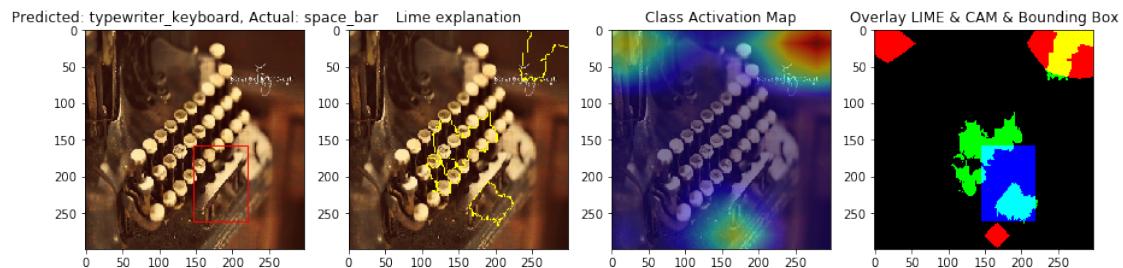


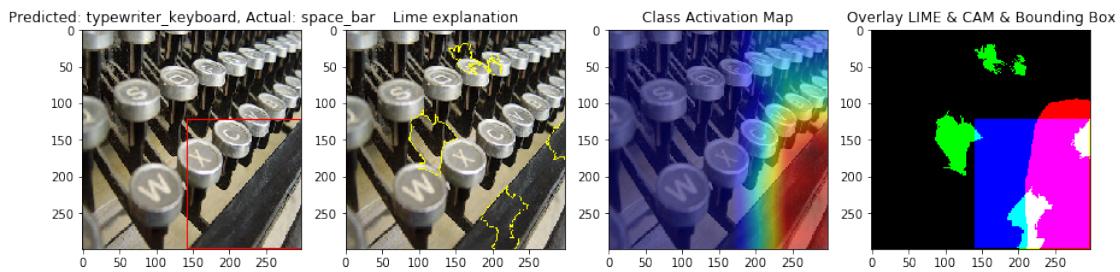
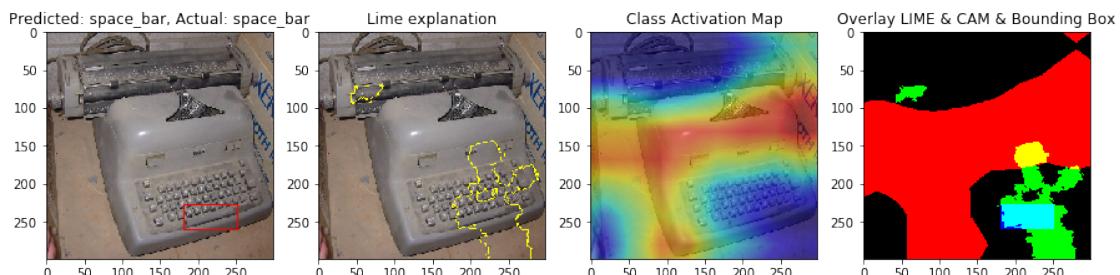
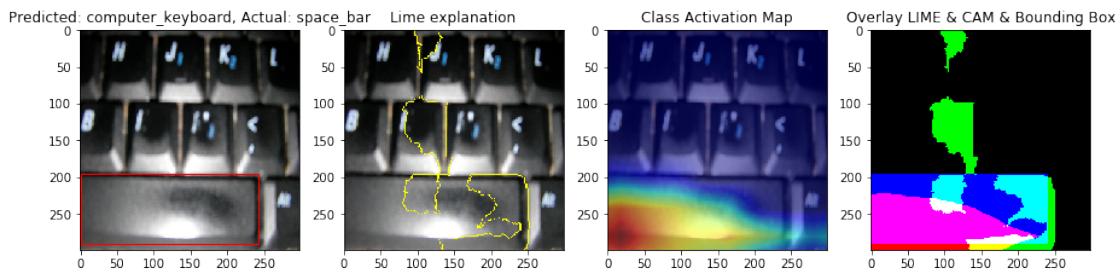
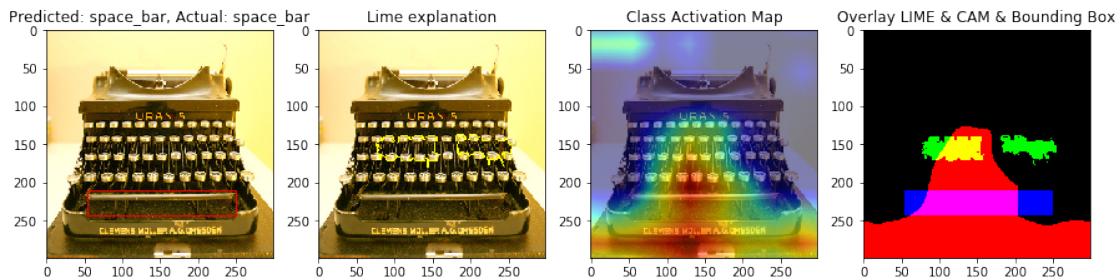


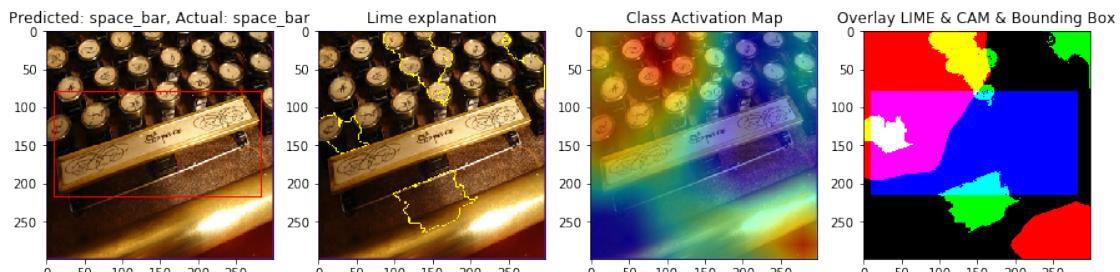
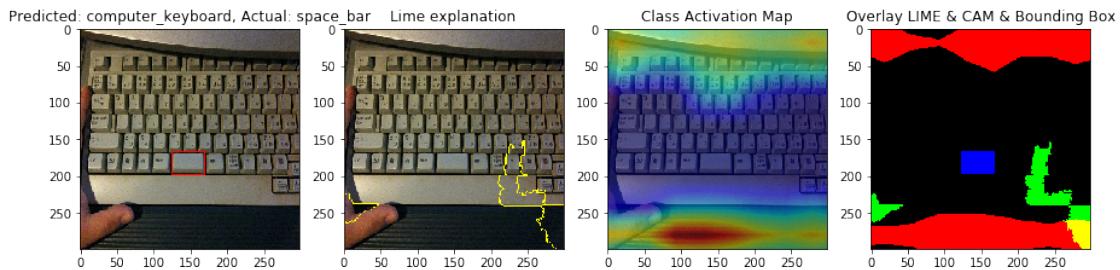
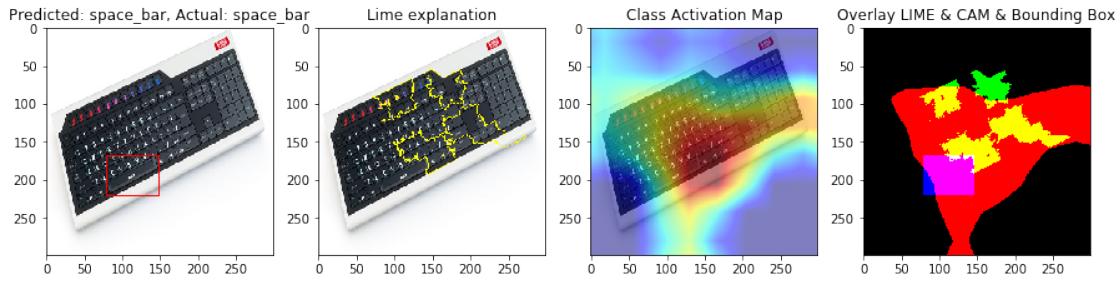
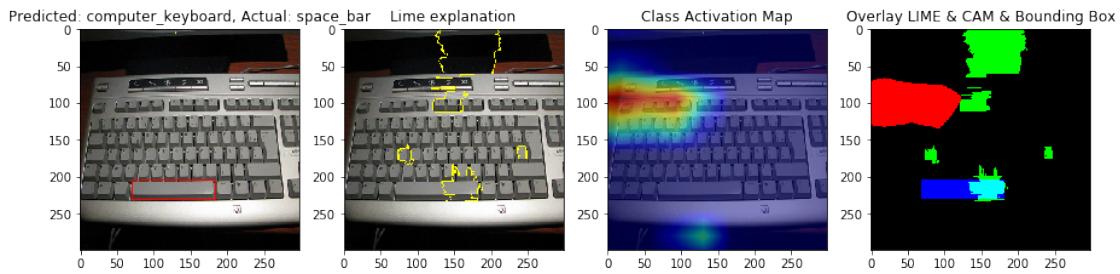












Get duplicated images in different classes by comparing their hash sums

```
[68]: hash_sums = pd.read_hdf('hashsums.h5', key = 'md5sums')
```

```
[69]: hash_sums[hash_sums.duplicated(['md5'])]
```

```
[69]:   class          file           md5
0  n04505470  n04505470_4387.jpg  8048af7aae2b9813ba43ded6c139e3a0
0  n04505470  n04505470_1600.jpg  327e2aa32a5ad356a1a3043dbf25ddae
0  n04505470  n04505470_1819.jpg  4852f9fe8a3ea99bf50b6eacd75f04af
0  n04505470  n04505470_3089.jpg  d2bef58ced592e683c6197b330c8842c
0  n04505470  n04505470_3418.jpg  31cf59963537d2a110eef45dfadfb70b
0  n04505470  n04505470_4717.jpg  1c69e7df9b12dc40a35f36a39ae94bce
0  n04505470  n04505470_2929.jpg  ae719aa030834ab6a0e56ef56677fccec
0  n04505470  n04505470_5057.jpg  aa03e6e773f0e53861baafebf752dc38
0  n04505470  n04505470_623.jpg  daa91ea84b017b253cb28a140fc9e0a0
0  n04505470  n04505470_4635.jpg  9a630d47a7938f306bdb52ccba7e03fd
0  n04505470  n04505470_1632.jpg  e916dc6c30cfec31f37c33465c535005
0  n04505470  n04505470_4344.jpg  bf92c3f66ee0e907711f667b7dc42a96
0  n04505470  n04505470_2437.jpg  c946d1706e97091923e85f6569b312bf
0  n04505470  n04505470_1273.jpg  90177182e9fae47924e560151fda14d9
0  n04505470  n04505470_4646.jpg  c70dd4e937ced44ba805a5c905d3c70f
0  n04505470  n04505470_3425.jpg  eb66491dee55d8789d9e0e2188e6da44
0  n04264628  n04264628_579.jpg  a4dedaa5bac4f94450abd6fa816f7194
0  n04264628  n04264628_11984.jpg  a4dedaa5bac4f94450abd6fa816f7194
0  n04264628  n04264628_5529.jpg  e09712fa6cf2b2646a2ed85b5d715a18
0  n04264628  n04264628_11500.jpg  c46e5f1a26a3e2191e66c221a1c04688
0  n04264628  n04264628_9671.jpg  a9ece9f7e4d762ada75b73543f79f397
0  n03832673  n03832673_11533.jpg  9fa92749ffb0c9c01f40717bcad53d8c
```

```
[70]: # duplicated hash_sum
```

```
hash_sums[hash_sums['md5'] == '9fa92749ffb0c9c01f40717bcad53d8c']
```

```
[70]:   class          file           md5
0  n03085013  n03085013_19020.jpg  9fa92749ffb0c9c01f40717bcad53d8c
0  n03832673  n03832673_11533.jpg  9fa92749ffb0c9c01f40717bcad53d8c
```

```
[36]: def print_row(dataset_row):
```

```
    # get data
    file_name = dataset_row['filename']
    actual_image_class = dataset_row['imageClass']
    actual_image_class_index = dataset_row['imageClassID']
    actual_image_class_name = label_list['{}'.
→format(actual_image_class_index)][1]
    cam_map = dataset_row['attentionMap']
    cam_mask = get_cam_mask(cam_map)
    lime_mask = dataset_row['LimeMask']
    bounding_boxes = dataset_row['boundingBoxes']
    bounding_box_mask = get_bounding_box_mask(bounding_boxes)
    predictions = dataset_row['prediction']
```

```

predicted_image_class_index = np.argmax(predictions)
predicted_image_class = label_list['{}'.
→format(predicted_image_class_index)][0]
predicted_image_class_name = label_list['{}'.
→format(predicted_image_class_index)][1]

# get rank of actual label in predictions
y = predictions.argsort()
rank = (len(y) - np.argwhere(y == actual_image_class_index))[0][0]

masks = np.zeros((299,299,3))
masks[:, :, 0] = cam_mask
masks[:, :, 1] = lime_mask
masks[:, :, 2] = bounding_box_mask

image = load_img("{} / {} / {}".format(base_path, actual_image_class, ↳
file_name), target_size = (299,299))
image = np.array(image)
image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
fig, ax = plt.subplots(1,4, figsize = (15,15))

ax[0].imshow(image[0])

for bounding_box in bounding_boxes:
    rect = patches.
→Rectangle((bounding_box['xminScalled'],bounding_box['yminScalled']),bounding_box['xdiffScal
    ax[0].add_patch(rect)

boundaries = mark_boundaries(image[0], lime_mask)

ax[0].set_title('Predicted: {}, Actual: {}'.
→format(predicted_image_class_name, actual_image_class_name))
ax[1].imshow(boundaries)
ax[1].set_title('Lime explanation')
ax[2].imshow(overlay(image[0],cam_map, alpha=0.5))
ax[2].set_title('Class Activation Map')
ax[3].imshow(masks)
ax[3].set_title('Overlay LIME & CAM & Bounding Box')

plt.show()

```

```
[37]: def loadBoundingBoxes(pathToXML, imageSizeX, imageSizeY):
    returnValues = []
    root = ET.parse(pathToXML).getroot()
    xmlImageX = root.findall('size/width')
    xmlImageY = root.findall('size/height')
```

```

if len(xmlImageY) != 1:
    print("ERROR: more than 1 image height found")
if len(xmlImageX) != 1:
    print("ERROR: more than 1 image width found")
xmlImageX = int(xmlImageX[0].text)
xmlImageY = int(xmlImageY[0].text)

#print("xmlPictureSize: X: {}, Y: {}".format(xmlImageX, xmlImageY))

xScalingFactor = imageSizeX*1.0 / xmlImageX
yScalingFactor = imageSizeY*1.0 / xmlImageY
#print("scaling factors x={} y={}".format(xScalingFactor, yScalingFactor))

for bndbox in root.findall('object/bndbox'):
    boundingBox = {}
    for child in bndbox:
        boundingBox[child.tag] = int(child.text)
    boundingBox['xminScalled'] = int(boundingBox['xmin']*xScalingFactor)
    boundingBox['yminScalled'] = int(boundingBox['ymin']*yScalingFactor)
    boundingBox['xmaxScalled'] = int(boundingBox['xmax']*xScalingFactor)
    boundingBox['ymaxScalled'] = int(boundingBox['ymax']*yScalingFactor)
    boundingBox['xdiff'] = boundingBox['xmax'] - boundingBox['xmin']
    boundingBox['ydiff'] = boundingBox['ymax'] - boundingBox['ymin']
    boundingBox['xdiffScalled'] = boundingBox['xmaxScalled'] - boundingBox['xminScalled']
    boundingBox['ydiffScalled'] = boundingBox['ymaxScalled'] - boundingBox['yminScalled']
    returnValues.append(boundingBox)
print(returnValues)
return(returnValues)

```

[ ]: