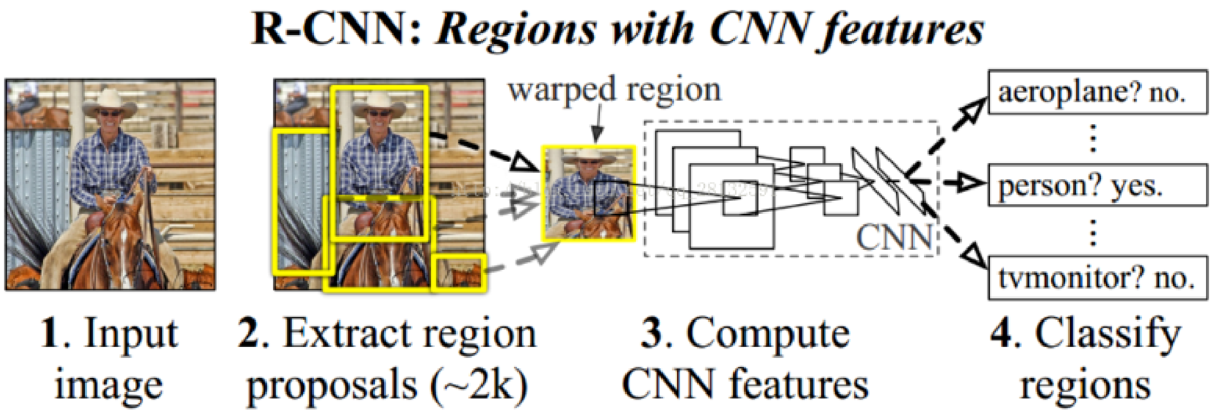
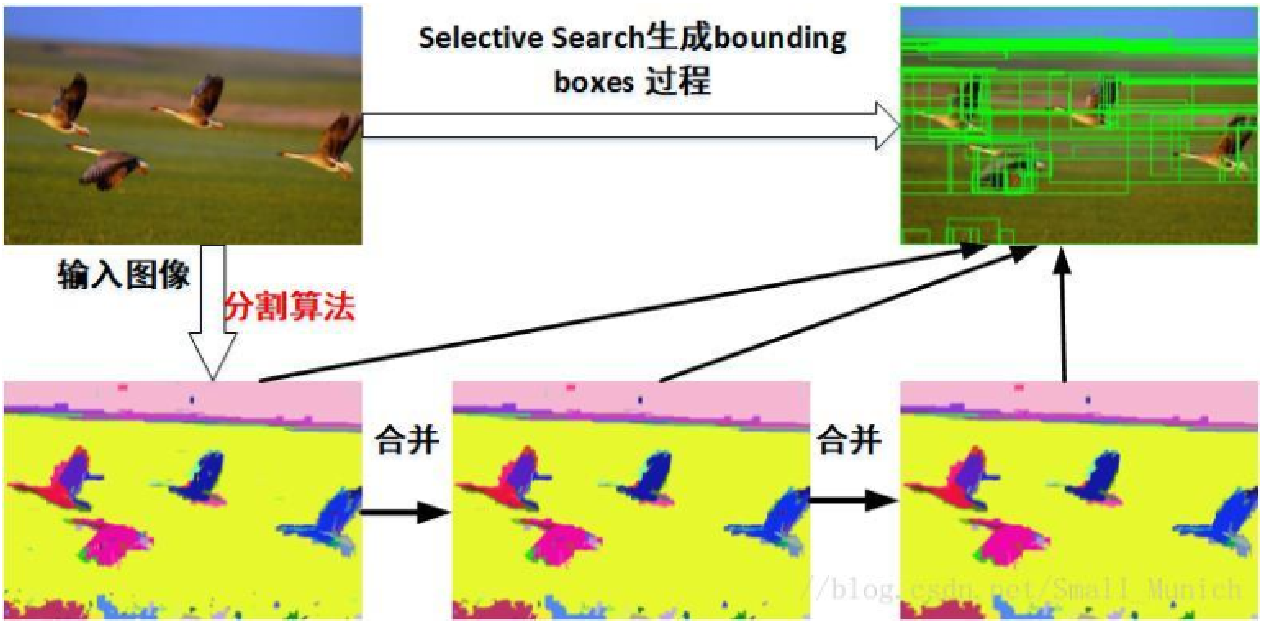
Selective Search算法



- 主要思路：输入一张图片，首先通过图像分割的方法获得很多小的区域，然后对这些小的区域不断进行合并，一直到无法合并为止。此时这些原始的小区域和合并得到的区域就是我们得到的bounding box。

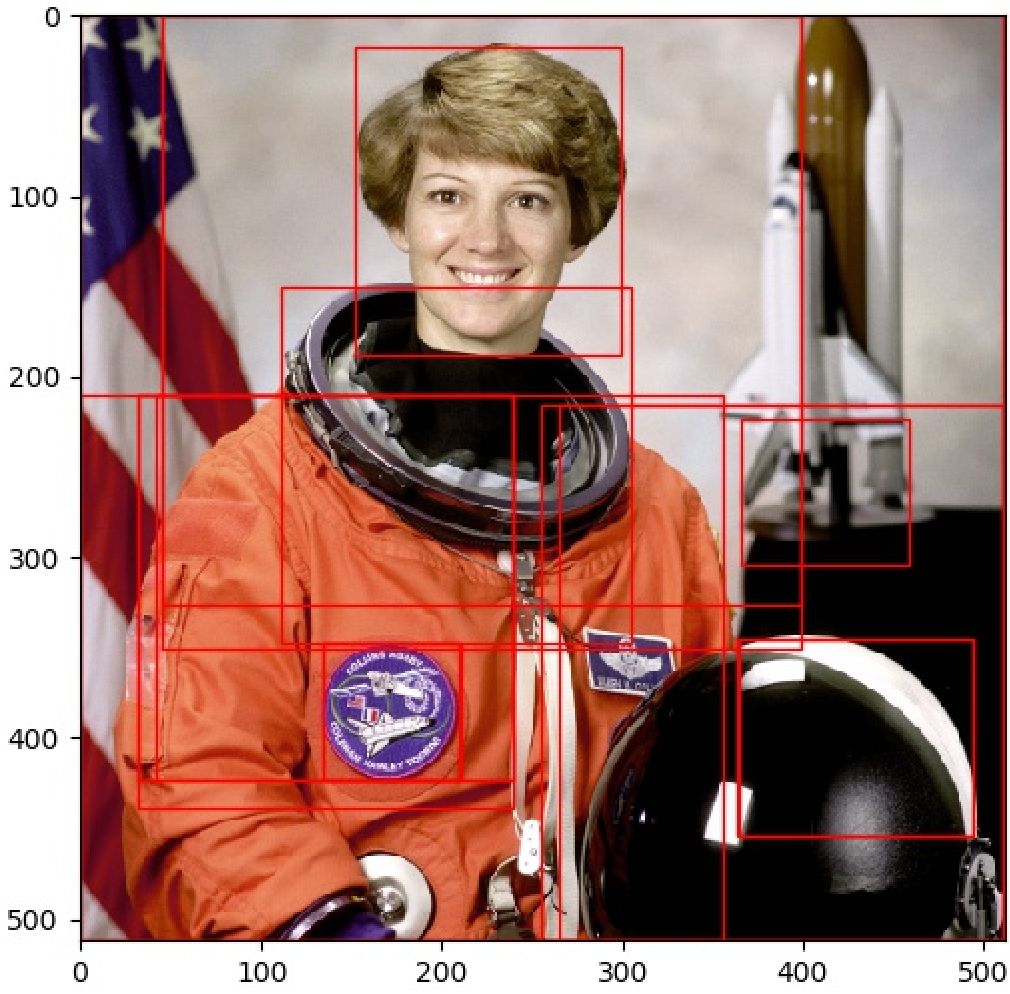


- 算法分为如下几步：
    - 生成原始的区域集 `R`
    - 计算区域集R里每个相邻区域的相似度 `S = {s1,s2,...}`。
    - 找出相似度最高的两个区域，将其合并为新集，添加进 `R`。
    - 从 `S` 中移除所有与第三步中有关的子集。
    - 计算新集与所有子集的相似度。
    - 跳至第三步，不断循环，合并，直至S为空。（到不能合并为止）
- python代码实现

```
import skimage.data
import selectivesearch

img = skimage.data.astronaut()
```

```
img_lbl, regions = selectivesearch.selective_search(img, scale=500, sigma=0.9, min_size=10)
print(regions[:10])
#输出
[{'labels': [0.0], 'rect': (0, 0, 15, 24), 'size': 260},
 {'labels': [1.0], 'rect': (13, 0, 1, 12), 'size': 23},
 {'labels': [2.0], 'rect': (0, 15, 15, 11), 'size': 30},
 {'labels': [3.0], 'rect': (15, 14, 0, 0), 'size': 1},
 {'labels': [4.0], 'rect': (0, 0, 61, 153), 'size': 4927},
 {'labels': [5.0], 'rect': (0, 12, 61, 142), 'size': 177},
 {'labels': [6.0], 'rect': (7, 54, 6, 17), 'size': 8},
 {'labels': [7.0], 'rect': (28, 50, 18, 32), 'size': 22},
 {'labels': [8.0], 'rect': (2, 99, 7, 24), 'size': 24},
 {'labels': [9.0], 'rect': (14, 118, 79, 117), 'size': 4008}]
```



源码分析

- 用户生成原始区域集的函数，其中用到了felzenszwalb图像分割算法。每一个区域都有一个编号，将编号并入图片中，方便后面的操作。

```python
def _generate_segments(im_orig, scale, sigma, min_size):
    """
        segment smallest regions by the algorithm of Felzenswalb and
        Huttenlocher
    """

    # open the Image
    im_mask = skimage.segmentation.felzenszwalb(
        skimage.util.img_as_float(im_orig), scale=scale, sigma=sigma,
        min_size=min_size)

    # merge mask channel to the image as a 4th channel
    im_orig = numpy.append(
        im_orig, numpy.zeros(im_orig.shape[:2])[:, :, numpy.newaxis], axis=2)
    im_orig[:, :, 3] = im_mask

    return im_orig
```

- 计算两个区域的相似度

  颜色和纹理相似度，通过获取两个区域的直方图的交集来判断相似度。

  最后相似度是四种相似度的加和。

3.1、颜色相似度（color similarity）

将色彩空间转为HSV，每个通道下以bins=25计算直方图，这样每个区域的颜色直方图有25*3=75个区间。 对直方图除以区域尺寸做归一化后使用下式计算相似度：

$$s_{colour}(r_i, r_j) = \sum_{k=1}^{n} \min(c_i^k, c_j^k)$$

3.2、纹理相似度（texture similarity）

论文采用方差为1的高斯分布在8个方向做梯度统计，然后将统计结果（尺寸与区域大小一致）以bins=10计算直方图。直方图区间数为8*3*10=240（使用RGB色彩空间）。

$$s_{texture}(r_i, r_j) = \sum_{k=1}^{n} min(t_i^k, t_j^k)$$

其中，t_i^k是直方图中第k^{th}个bin的值。

3.3、尺寸相似度（size similarity）

$$s_{size}(r_i, r_j) = 1 - \frac{size(r_i) + size(r_j)}{size(im)}$$

保证合并操作的尺度较为均匀，避免一个大区域陆续“吃掉”其他小区域。

例：设有区域a-b-c-d-e-f-g-h。较好的合并方式是：ab-cd-ef-gh -> abcd-efgh -> abcdefgh。 不好的合并方法是：ab-c-d-e-f-g-h ->abcd-e-f-g-h ->abcdef-gh -> abcdefgh。

3.4、交叠相似度（shape compatibility measure）

$$s_{fill}(r_i, r_j) = 1 - \frac{size(BB_{ij}) - size(r_i) - size(r_j)}{size(im)}$$

3.5、最终的相似度

$$s(r_i, r_j) = a_1 s_{color}(r_i, r_j) + a_2 s_{texture}(r_i, r_j) + a_3 s_{size}(r_i, r_j) + a_4 s_{fill}(r_i, r_j)$$

```
#颜色
def _sim_colour(r1, r2):
    return sum([min(a, b) for a, b in zip(r1["hist_c"], r2["hist_c"])])

#纹理
def _sim_texture(r1, r2):
    return sum([min(a, b) for a, b in zip(r1["hist_t"], r2["hist_t"])])

#尺寸
def _sim_size(r1, r2, imsize):
    return 1.0 - (r1["size"] + r2["size"]) / imsize

#交叠部分
def _sim_fill(r1, r2, imsize):
    bbsize = (
        (max(r1["max_x"], r2["max_x"]) - min(r1["min_x"], r2["min_x"]))
        * (max(r1["max_y"], r2["max_y"]) - min(r1["min_y"], r2["min_y"]))
    )
    return 1.0 - (bbsize - r1["size"] - r2["size"]) / imsize

#相似度相加和
def _calc_sim(r1, r2, imsize):
    return (_sim_colour(r1, r2) + _sim_texture(r1, r2)
            + _sim_size(r1, r2, imsize) + _sim_fill(r1, r2, imsize))
```

- 用于计算颜色和纹理的直方图的函数

```
def _calc_colour_hist(img):
```

```
    """
        calculate colour histogram for each region
        the size of output histogram will be BINS * COLOUR_CHANNELS(3)
        number of bins is 25 as same as [uijlings_ijcv2013_draft.pdf]
        extract HSV
    """

    BINS = 25
    hist = numpy.array([])

    for colour_channel in (0, 1, 2):

        # extracting one colour channel
        c = img[:, colour_channel]

        # calculate histogram for each colour and join to the result
        hist = numpy.concatenate(
            [hist] + [numpy.histogram(c, BINS, (0.0, 255.0))[0]])

    # L1 normalize
    hist = hist / len(img)

    return hist


def _calc_texture_gradient(img):
    """
        calculate texture gradient for entire image
        The original SelectiveSearch algorithm proposed Gaussian derivative
        for 8 orientations, but we use LBP instead.
        output will be [height(*)][width(*)]
    """
    ret = numpy.zeros((img.shape[0], img.shape[1], img.shape[2]))

    for colour_channel in (0, 1, 2):
        ret[:, :, colour_channel] = skimage.feature.local_binary_pattern(
            img[:, :, colour_channel], 8, 1.0)

    return ret


def _calc_texture_hist(img):
    """
        calculate texture histogram for each region
        calculate the histogram of gradient for each colours
        the size of output histogram will be
            BINS * ORIENTATIONS * COLOUR_CHANNELS(3)
    """
    BINS = 10

    hist = numpy.array([])

    for colour_channel in (0, 1, 2):
```

```
        # mask by the colour channel
        fd = img[:, colour_channel]

        # calculate histogram for each orientation and concatenate them all
        # and join to the result
        hist = numpy.concatenate(
            [hist] + [numpy.histogram(fd, BINS, (0.0, 1.0))[0]])

    # L1 Normalize
    hist = hist / len(img)

    return hist
```

- 提取区域的尺寸、颜色和纹理特征

```
def _extract_regions(img):

    R = {}

    # get hsv image
    hsv = skimage.color.rgb2hsv(img[:, :, :3])

    # pass 1: count pixel positions
    for y, i in enumerate(img):

        for x, (r, g, b, l) in enumerate(i):

            # initialize a new region
            if l not in R:
                R[l] = {
                    "min_x": 0xffff, "min_y": 0xffff,
                    "max_x": 0, "max_y": 0, "labels": [l]}

            # bounding box
            if R[l]["min_x"] > x:
                R[l]["min_x"] = x
            if R[l]["min_y"] > y:
                R[l]["min_y"] = y
            if R[l]["max_x"] < x:
                R[l]["max_x"] = x
            if R[l]["max_y"] < y:
                R[l]["max_y"] = y

    # pass 2: calculate texture gradient
    tex_grad = _calc_texture_gradient(img)

    # pass 3: calculate colour histogram of each region
    for k, v in list(R.items()):

        # colour histogram
```

```
        masked_pixels = hsv[:, :, :][img[:, :, 3] == k]
        R[k]["size"] = len(masked_pixels / 4)
        R[k]["hist_c"] = _calc_colour_hist(masked_pixels)

        # texture histogram
        R[k]["hist_t"] = _calc_texture_hist(tex_grad[:, :][img[:, :, 3] == k])

    return R
```

- 找邻居 -- 通过计算每个区域与其余的所有区域是否有相交，来判断是不是邻居。

```
def _extract_neighbours(regions):

    def intersect(a, b):
        if (a["min_x"] < b["min_x"] < a["max_x"]
                and a["min_y"] < b["min_y"] < a["max_y"]) or (
            a["min_x"] < b["max_x"] < a["max_x"]
                and a["min_y"] < b["max_y"] < a["max_y"]) or (
            a["min_x"] < b["min_x"] < a["max_x"]
                and a["min_y"] < b["max_y"] < a["max_y"]) or (
            a["min_x"] < b["max_x"] < a["max_x"]
                and a["min_y"] < b["min_y"] < a["max_y"]):
            return True
        return False

    R = list(regions.items())
    neighbours = []
    for cur, a in enumerate(R[:-1]):
        for b in R[cur + 1:]:
            if intersect(a[1], b[1]):
                neighbours.append((a, b))

    return neighbours
```

- 合并两个区域的函数

```
def _merge_regions(r1, r2):
    new_size = r1["size"] + r2["size"]
    rt = {
        "min_x": min(r1["min_x"], r2["min_x"]),
        "min_y": min(r1["min_y"], r2["min_y"]),
        "max_x": max(r1["max_x"], r2["max_x"]),
        "max_y": max(r1["max_y"], r2["max_y"]),
        "size": new_size,
        "hist_c": (
            r1["hist_c"] * r1["size"] + r2["hist_c"] * r2["size"]) / new_size,
        "hist_t": (
            r1["hist_t"] * r1["size"] + r2["hist_t"] * r2["size"]) / new_size,
        "labels": r1["labels"] + r2["labels"]
    }
```

```
    return rt
```

- 主函数---Selective Search
    - `scale`：图像分割的集群程度。值越大，意味集群程度越高，分割的越少，获得子区域越大。默认为1
    - `sigma`：图像分割前，会先对原图像进行高斯滤波去噪，sigma即为高斯核的大小。默认为0.8
    - `min_size`：最小的区域像素点个数。当小于此值时，图像分割的计算就停止，默认为20

`每次选出相似度最高的一组区域（如编号为100和120的区域），进行合并，得到新的区域（如编号为300）。然后计算新的区域300与区域100的所有邻居和区域120的所有邻居的相似度，加入区域集S。不断循环，直到S为空，此时最后只剩下一个区域，而且它的像素数会非常大，接近原始图片的像素数，因此无法继续合并。最后退出程序。`

```
def selective_search(
        im_orig, scale=1.0, sigma=0.8, min_size=50):
    '''Selective Search
    Parameters
    ----------
        im_orig : ndarray
            Input image
        scale : int
            Free parameter. Higher means larger clusters in felzenszwalb segmentation.
        sigma : float
            Width of Gaussian kernel for felzenszwalb segmentation.
        min_size : int
            Minimum component size for felzenszwalb segmentation.
    Returns
    -------
        img : ndarray
            image with region label
            region label is stored in the 4th value of each pixel [r,g,b,(region)]
        regions : array of dict
            [
                {
                    'rect': (left, top, width, height),
                    'labels': [...],
                    'size': component_size
                },
                ...
            ]
    '''
    assert im_orig.shape[2] == 3, "3ch image is expected"

    # load image and get smallest regions
    # region label is stored in the 4th value of each pixel [r,g,b,(region)]
    img = _generate_segments(im_orig, scale, sigma, min_size)

    if img is None:
        return None, {}

    imsize = img.shape[0] * img.shape[1]
    R = _extract_regions(img)

    # extract neighbouring information
```

```python
    neighbours = _extract_neighbours(R)

    # calculate initial similarities
    S = {}
    for (ai, ar), (bi, br) in neighbours:
        S[(ai, bi)] = _calc_sim(ar, br, imsize)

    # hierarchal search
    while S != {}:

        # get highest similarity
        i, j = sorted(S.items(), key=lambda i: i[1])[-1][0]

        # merge corresponding regions
        t = max(R.keys()) + 1.0
        R[t] = _merge_regions(R[i], R[j])

        # mark similarities for regions to be removed
        key_to_delete = []
        for k, v in list(S.items()):
            if (i in k) or (j in k):
                key_to_delete.append(k)

        # remove old similarities of related regions
        for k in key_to_delete:
            del S[k]

        # calculate similarity set with the new region
        for k in [a for a in key_to_delete if a != (i, j)]:
            n = k[1] if k[0] in (i, j) else k[0]
            S[(t, n)] = _calc_sim(R[t], R[n], imsize)

    regions = []
    for k, r in list(R.items()):
        regions.append({
            'rect': (
                r['min_x'], r['min_y'],
                r['max_x'] - r['min_x'], r['max_y'] - r['min_y']),
            'size': r['size'],
            'labels': r['labels']
        })

    return img, regions
```

[Selective Search源码地址]