COMP 204
Introduction to image analysis with scikit-image (part three)

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based on slides from Mathieu Blanchette, Christopher J.F. Cameron and Carlos G. Oliver
Outline

Correction from blur function in last lecture

Edge detection

Edge detection using thresholding approach

Counting cells by seed-filling algorithm

Final review
Blurring an image (recap)

Blurring is achieved by replacing each pixel by the average value of the pixels in a small window centered on it.

Example, window of size 5:
Different window sizes led to different blurring effects

Original

Window size = 5

Window size = 21

Window size = 101
Blurring an image (version with mixed up names)

index \( i \) indicates rows, therefore bottom (bot) and top
index \( j \) indicates columns, therefore left and right

**lines 13-20** mix up the names. We still get correct output, why?

```python
def blur(image, filter_size):
    n_row, n_col, colors = image.shape
    blurred_image = np.zeros((n_row, n_col, colors),
                              dtype=np.uint8)
    half_size = int(filter_size/2)
    for i in range(n_row):
        for j in range(n_col):
            # define the boundaries of window around \((i,j)\)
            left = max(0, i-half_size)
            right = min(i+half_size, n_row)
            bot = max(0, j-half_size)
            top = min(n_col, j+half_size)

            # calculate average of RGB values in window
            blurred_image[i,j] =
                image[left:right, bot:top, :].max(axis=(0,1))

    return blurred_image
```

Blurring an image (correct version)

index $i$ indicates rows, therefore bottom (bot) and top
index $j$ indicates columns, therefore left and right
pay attention to **lines 13-20**

```python
def blur(image, filter_size):
    n_row, n_col, colors = image.shape
    blurred_image = np.zeros((n_row, n_col, colors),
        dtype=np.uint8)
    half_size=int(filter_size/2)
    for i in range(n_row):
        for j in range(n_col):
            # define the boundaries of window around $(i,j)$
            bot=max(0,i-half_size)
            top=min(i+half_size,n_row)
            left=max(0,j-half_size)
            right=min(n_col,j+half_size)

            # calculate average of RGB values in window
            blurred_image[i,j] = \
                image[bot:top,left:right,:].max(axis=(0,1))

    return blurred_image
```

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Edge detection

Goal: Identify regions of the image that contain sharp changes in colors/intensities.
Why? Useful for
- delineating objects (image segmentation)
- recognizing them (object recognition)
- automatically counting cells from an imaging scan (discussed in Section 4)
Edge detection
Color edge detection
Edge detection

What’s an edge in an image? sharp transition between color tones

Vertical edge at row $i$:

- $image[i - 1, j]$ is very different from $image[i + 1, j]$

Horizontal edge at column $j$:

- $image[i, j - 1]$ is very different from $image[i, j + 1]$

Idea: To determine if an RGB pixel $(i, j)$ belongs to an edge:
For each color $\in \{ R, G, B \}$:

- $L_x[color] = image[i, j - 1, color] - image[i, j + 1, color]$
- $L_y[color] = image[i - 1, j, color] - image[i + 1, j, color]$
- $edge_{image}[i,j,color] = \sqrt{L_x[color]^2 + L_y[color]^2}$
def detect_edges(image):
    n_row, n_col, colors = image.shape
    edge_image = np.zeros((n_row,n_col,3), dtype=np.uint8)

    for i in range(1,n_row-1):
        for j in range(1,n_col-1):
            for c in range(3):

                # conversion to int needed to accommodate
                # for potentially negative values

                d_r = int(image[i-1,j,c]) - int(image[i+1,j,c])
                d_c = int(image[i,j-1,c]) - int(image[i,j+1,c])

                gradient = math.sqrt(d_r**2+d_c**2)

                # limit value to 255

                edge_image[i,j,c]=np.uint8(min(255,gradient))

    return edge_image
Edge detection on monkey image
Edge detection on monkey image

Not so great if our goal is to find the monkey in the image!
Blurring (Lecture 33) + Edge detection

To smooth out fine details like leaves:
Start by blurring the image, then apply edge detection.
Analysis of microscopy images
Analysis of microscopy images
Outline

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Final review
Edge detection using a thresholding approach
Edge detection with thresholds

Same as the colour edge detections but the two last lines below.

Horizontal edge at row $i$:

- $image[i - 1, j]$ is very different from $image[i + 1, j]$

Vertical edge at column $j$:

- $image[i, j - 1]$ is very different from $image[i, j + 1]$

Idea: To determine if an RGB pixel $(i, j)$ belongs to an edge:

For each color $\in \{R, G, B\}$:

- $L_x[color] = image[i, j - 1, color] - image[i, j + 1, color]$
- $L_y[color] = image[i - 1, j, color] - image[i + 1, j, color]$
- $gradient[color] = \sqrt{L_x[color]^2 + L_y[color]^2}$

$edginess = \sqrt{gradient[R]^2 + gradient[G]^2 + gradient[B]^2}$

If $edginess > \text{some\_threshold}$, then pixel $(i, j)$ belongs to an edge
def detect_edges(im, min_gradient=50):
    
    # Args:
    # im: The image on which to detect edges
    # min_gradient: The minimum gradient value for a pixel to be called an edge
    # Returns: An new image with edge pixels set to white, and everything else set to black

    n_row, n_col, colors = image.shape
    edge_image = np.zeros((n_row, n_col, 3), dtype=np.uint8)

    for i in range(1, n_row - 1):
        for j in range(1, n_col - 1):
            grad = [0, 0, 0]
            for c in range(3):
                Lx = float(im[i - 1, j, c]) - float(im[i + 1, j, c])
                Ly = float(im[i, j - 1, c]) - float(im[i, j + 1, c])
                grad[c] = math.sqrt(Lx ** 2 + Ly ** 2)
            if (norm > min_gradient):
                edge_image[i, j] = (255, 255, 255)
    return edge_image
Analysis of microscopy images

Cells (purple "circles") are infected by Plasmodium falciparum (small red dots).
Edge detection (threshold = 60)
Edge detection (threshold = 120)
Edge detection

Skimage has many edge detection algorithms:
http://scikit-image.org/docs/0.5/auto_examples/plot_canny.html
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Final review
Counting/annotating cells

What if we want to automatically identify/count cells in the image?

Idea:

1. Find edges in the image

2. Identify closed (encircled) shapes within the edge image

Each closed shape is assigned a different color.
Number of closed shapes (≈ approximation to cell count) is calculated.
Seed filling algorithm

How to take an edge image and fill-in each closed shape?
Seed filling (aka flood filling) algorithm:

▶ Start from a black pixel.
▶ Color it and expand to its neighboring pixel, unless neighbor is an edge (white).
▶ Keep expanding until no more expansion is possible
▶ Repeat from a new starting point, until no black pixels are left
Seed filling algorithm

For illustration purpose, we swapped the background and edge colors: Black = edge, white = background
Seed = pixel at position (4,4)

In our real image, Black = background, white = edge
```python
def seedfill(im, seed_row, seed_col, fill_color, bckg):
    """
    im: The image on which to perform the seedfill algorithm
    seed_row and seed_col: position of the seed pixel
    fill_color: Color for the fill
    bckg: Color of the background, to be filled
    Returns: Nothing
    Behavior: Modifies image by performing seedfill
    """
    size = 0  # keep track of patch size
    n_row, n_col, foo = im.shape
    front = [(seed_row, seed_col)]  # initial front

    while len(front) > 0:
        r, c = front.pop(0)  # remove 1st element of front
        if np.array_equal(im[r, c, :], bckg):
            im[r, c] = fill_color  # color pixel
            size += 1
            # look at all neighbors
            for i in range(max(0, r - 1), min(n_row, r + 2)):
                for j in range(max(0, c - 1), min(n_col, c + 2)):
                    if np.array_equal(im[i, j, :], bckg) and
                    (i, j) not in front:
                        front.append((i, j))
        return size
```

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Seed filling implementation

```
Seeding from all possible starting pixel...

```python
min_cell_size=100  # based on prior knowledge
max_cell_size=300  # based on prior knowledge
n_cells=0

# look for a black pixel to seed the filling
for i in range(image.shape[0]):
    for j in range(image.shape[1]):
        if np.array_equal(edge[i,j,:],(0,0,0)):
            rand_color = (random.randrange(255),
                           random.randrange(255),
                           random.randrange(255))
            size=seedfill_with_animation(edge, i ,j,
                                          rand_color,
                                          )

            if size>= min_cell_size and size<max_cell_size:
                n_cells+=1

print("Number of cells:",n_cells)
```
Seed filling execution

See live execution of program
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Final review
Date and Time: Tuesday, April 30, 2019 at 6:30:00 PM
Room: TBD
In the next 3 lectures, we will review the course materials tested in the final exam
Materials tested in the final exam

Main materials that are covered in the final exam include:

► Basics: functions, loops, variables, data types (string, list, tuple, dictionary, sets), difference between pass by copy and pass by memory addresses

► Algorithms: Searching (linear and binary search) and sorting (insertion and selection sort)

► Pattern searching by string indexing and regular expression (simple ones)

► Object oriented programming: class, attributes, class inheritance, class methods

► BioPython sequence handling covered in class (I will remind you what the methods are in the exam)

► Machine learning: know what supervised, unsupervised, reinforcement learning are, problems they can solve, TPR, FPR, overfitting, cross-validation, ROC, decision trees

► Image processing: basic understanding of going from a pixel in the image to numpy ndarray