EN3160 Assignment 2: Fitting and Alignment

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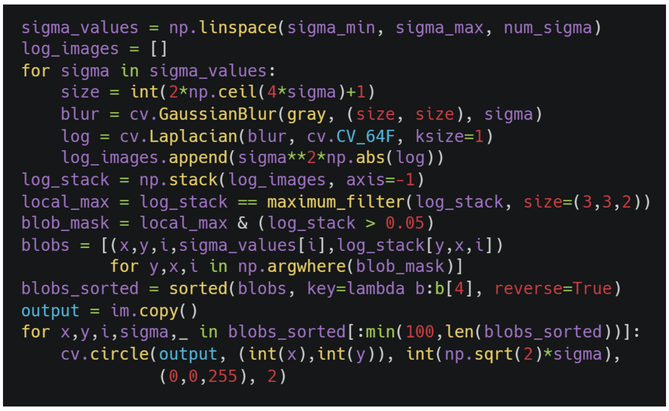
Project Repository: Fitting-and-Alignment

Question 1: Blob Detection on Sunflower Field



```python
sigma_values = np.linspace(sigma_min, sigma_max, num_sigma)
log_images = []
for sigma in sigma_values:
    size = int(2*np.ceil(4*sigma)+1)
    blur = cv.GaussianBlur(gray, (size, size), sigma)
    log = cv.Laplacian(blur, cv.CV_64F, ksize=1)
    log_images.append(sigma**2*np.abs(log))
log_stack = np.stack(log_images, axis=-1)
local_max = log_stack == maximum_filter(log_stack, size=(3,3,2))
blob_mask = local_max & (log_stack > 0.05)
blobs = [(x,y,i,sigma_values[i],log_stack[y,x,i])
         for y,x,i in np.argwhere(blob_mask)]
blobs_sorted = sorted(blobs, key=lambda b:b[4], reverse=True)
output = im.copy()
for x,y,i,sigma,_ in blobs_sorted[:min(100,len(blobs_sorted))]:
    cv.circle(output, (int(x),int(y)), int(np.sqrt(2)*sigma),
              (0,0,255), 2)
```

Figure 1: Blob Detection using Scale-space LoG

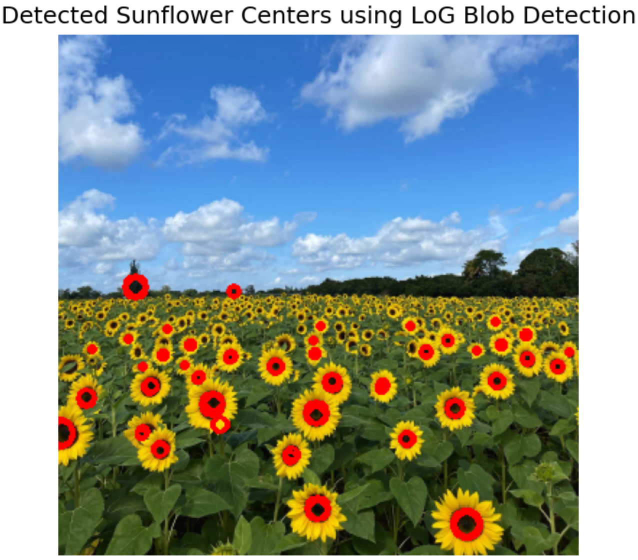


Figure 2: Detected Blobs over Multiple Scales

LoG Scale-Space Parameters

σ range	[2, 20]
Scales	50
Shape	(360, 360, 50)
Total blobs	4611
Threshold	0.05
Neighborhood	(3, 3, 2)

Top 5 Largest Circles (by radius)

Rank	X	Y	σ	Radius	Response
1	47	0	20.000	28.28	0.102926
2	295	0	20.000	28.28	0.069862
3	68	31	20.000	28.28	0.075601
4	69	33	20.000	28.28	0.075608
5	310	50	20.000	28.28	0.065867

Question 2: Line and Circle Fitting with RANSAC

Line Estimation using RANSAC

a	0.71
b	0.70
d	-1.48
Number of inliers	35

Circle Estimation using RANSAC

Center (x_0, y_0)	(2.12, 2.35)
Radius r	9.88
Number of inliers	52

(d) Circle-First Approach Analysis

If we fit the circle first, many line points appear as outliers and distort the estimate. The circle fitting RANSAC would try to include them, causing incorrect center and radius, poor inlier classification, and degraded line fitting due to misclassified points. Thus, it's better to fit the line first, remove its inliers, then fit the circle.

Listing 1: RANSAC Line Fitting

```
def fit_line(points):
    """Fit line ax + by + d = 0
       through two points."""
    (x1, y1), (x2, y2) = points
    a = y1 - y2
    b = x2 - x1
    d = -(a * x1 + b * y1)
    norm = np.sqrt(a**2 + b**2)
    return a/norm, b/norm, d/norm

def line_distance(a, b, d, X):
    """Compute normal distance from
       line to all points."""
    return np.abs(a*X[:,0] + b*X[:,1]
       + d)

def ransac_line(X, n_iter=1000,
    threshold=0.6, min_inliers=35):
    best_inliers = []
    best_model = None
    for _ in range(n_iter):
        sample = X[np.random.choice(len
           (X), 2, replace=False)]
        a, b, d = fit_line(sample)
        distances = line_distance(a, b,
            d, X)
        inliers = X[distances <
           threshold]
        if len(inliers) > len(
           best_inliers):
           best_inliers = inliers
           best_model = (a, b, d)
    return best_model, best_inliers
```

Listing 2: RANSAC Circle Fitting

```
def fit_circle(pts):
    """Fit a circle through 3 points."""
    A = np.array([[2*(pts[1,0]-pts[0,0]), 2*(pts[1,1]-
       pts[0,1])],
                 [2*(pts[2,0]-pts[0,0]), 2*(pts[2,1]-
                    pts[0,1])]])
    b = np.array([(pts[1,0]**2 - pts[0,0]**2) +
                 (pts[1,1]**2 - pts[0,1]**2),
                 (pts[2,0]**2 - pts[0,0]**2) +
                 (pts[2,1]**2 - pts[0,1]**2)])
    center = np.linalg.solve(A, b)
    radius = np.sqrt((pts[0,0]-center[0])**2 +
                    (pts[0,1]-center[1])**2)
    return center, radius

def ransac_circle(X, n_iter=1000, threshold=1.5,
    min_inliers=45):
    best_inliers = []
    best_model = None
    for _ in range(n_iter):
        sample = X[np.random.choice(len(X), 3, replace
           =False)]
        try:
            center, r = fit_circle(sample)
        except np.linalg.LinAlgError:
            continue
        dist = np.sqrt((X[:,0]-center[0])**2 + (X
            [:,1]-center[1])**2)
        inliers = X[np.abs(dist - r) < threshold]
        if len(inliers) > len(best_inliers):
            best_inliers = inliers
            best_model = (center, r)
    return best_model, best_inliers
```

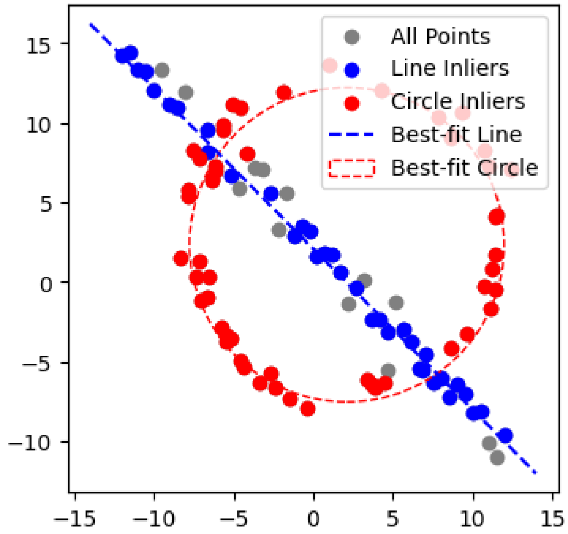


Figure 3: RANSAC line and circle fitting with inliers and sample points

Question 3: Homography and Flag Superimposition

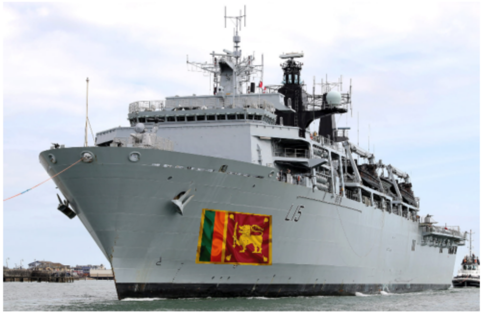
Listing 3: Homography Computation and Warping

```python
def compute_homography(src_pts, dst_pts):
    assert src_pts.shape[0] == dst_pts.shape[0] >= 4
    n = src_pts.shape[0]
    A = []
    for i in range(n):
        x, y = src_pts[i]
        u, v = dst_pts[i]
        A.append([-x, -y, -1, 0, 0, 0, u*x, u*y, u])
        A.append([0, 0, 0, -x, -y, -1, v*x, v*y, v])
    A = np.array(A)
    U, S, Vt = np.linalg.svd(A)
    H = Vt[-1].reshape(3, 3)
    H = H / H[2, 2]
    return H

def warp_image(src_img, H, dst_shape):
    h, w = dst_shape[:2]
    warped = np.zeros((h, w, 3), dtype=np.uint8)
    mask = np.zeros((h, w), dtype=np.uint8)
    H_inv = np.linalg.inv(H)
    y_coords, x_coords = np.mgrid[0:h, 0:w]
    ones = np.ones_like(x_coords)
    dst_coords = np.stack([x_coords, y_coords, ones], axis=-1)
    dst_coords_flat = dst_coords.reshape(-1, 3).T
    src_coords_flat = H_inv @ dst_coords_flat
    src_x = src_coords_flat[0] / src_coords_flat[2]
    src_y = src_coords_flat[1] / src_coords_flat[2]
    src_x = src_x.reshape(h, w)
    src_y = src_y.reshape(h, w)
    src_h, src_w = src_img.shape[:2]
    valid_mask = (src_x >= 0) & (src_x < src_w - 1) & \
                 (src_y >= 0) & (src_y < src_h - 1)
    x0 = np.floor(src_x).astype(int); x1 = x0 + 1
    y0 = np.floor(src_y).astype(int); y1 = y0 + 1
    x0 = np.clip(x0, 0, src_w - 1); x1 = np.clip(x1, 0, src_w - 1)
```

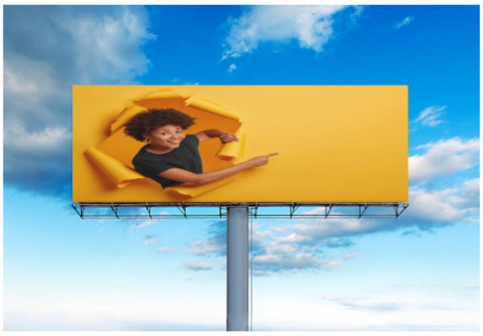
Listing 4: Blending and Processing

```python
    y0 = np.clip(y0, 0, src_h - 1); y1 = np.clip(y1, 0, src_h - 1)
    fx = src_x - x0; fy = src_y - y0
    for c in range(3):
        wa = (1 - fx) * (1 - fy); wb = fx * (1 - fy)
        wc = (1 - fx) * fy; wd = fx * fy
        warped[:, :, c] = (wa * src_img[y0, x0, c] +
                           wb * src_img[y0, x1, c] +
                           wc * src_img[y1, x0, c] +
                           wd * src_img[y1, x1, c])
    mask[valid_mask] = 255
    return warped, mask

def blend_images(dst_img, src_warped, mask, alpha=1.0):
    result = dst_img.copy()
    mask_3channel = cv.cvtColor(mask, cv.COLOR_GRAY2BGR) / 255.0
    result = (1 - alpha * mask_3channel) * result + alpha * mask_3channel * src_warped
    return result.astype(np.uint8)

def process_image_pair(src_img, dst_img, dst_points=None, alpha=1.0):
    h_src, w_src = src_img.shape[:2]
    src_pts = np.array([[0,0],[w_src-1,0],[w_src-1,h_src-1],[0,h_src-1]],dtype=np.float32)
    dst_pts = np.array(dst_points,dtype=np.float32) if dst_points is not None else select_points_interactive(dst_img)
    H = compute_homography(src_pts, dst_pts)
    warped, mask = warp_image(src_img, H, dst_img.shape)
    result = blend_images(dst_img, warped, mask, alpha)
    return result, H, dst_pts, warped, mask
```

Final Result (Blended)



Final Result (Blended)



$$\text{Homography: } \begin{bmatrix} 0.7950 & 0.0005649 & 88.0 \\ -0.001277 & 0.4167 & 103.0 \\ -1.2397 \times 10^{-5} & 6.4197 \times 10^{-6} & 1 \end{bmatrix}$$

$$\text{Homography: } \begin{bmatrix} 0.2201 & -0.08589 & 334.0 \\ 0.06482 & 0.11898 & 347.0 \\ 1.3509 \times 10^{-4} & -1.8554 \times 10^{-4} & 1 \end{bmatrix}$$

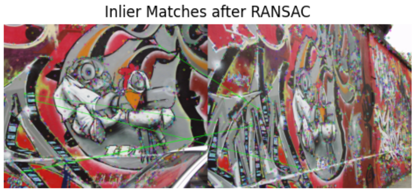
Question 4: Image Stitching

Listing 5: SIFT Feature Matching and RANSAC

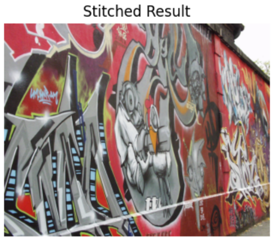
```python
def compute_sift_matches(img1,img2):
    sift=cv.SIFT_create()
    kp1,des1=sift.detectAndCompute(img1,None)
    kp2,des2=sift.detectAndCompute(img2,None)
    flann=cv.FlannBasedMatcher(dict(algorithm=1,trees=5),dict(checks=50))
    matches=flann.knnMatch(des1,des2,k=2)
    good_matches=[m for m,n in matches if m.distance<0.75*n.distance]
    print(f"Number of good matches: {len(good_matches)}")
    return kp1,kp2,good_matches

def ransac_homography(kp1,kp2,matches,threshold=5.0,iterations=2000):
    if len(matches)<4: raise ValueError("Not enough matches")
    pts1=np.float32([kp1[m.queryIdx].pt for m in matches])
    pts2=np.float32([kp2[m.trainIdx].pt for m in matches])
    best_H,max_inliers,best_mask=None,0,None
    for _ in range(iterations):
        idx=np.random.choice(len(matches),4,replace=False)
        H,_=cv.findHomography(pts1[idx],pts2[idx],0)
        if H is None: continue
        pts1_h=np.hstack((pts1,np.ones((pts1.shape[0],1))))
        pts2_proj=(H@pts1_h.T).T
```

Listing 6: Image Stitching

```python
        pts2_proj=pts2_proj[:,:2]/pts2_proj[:,2,np.newaxis]
        inliers=np.linalg.norm(pts2-pts2_proj,axis=1)<threshold
        if inliers.sum()>max_inliers:
            max_inliers,best_H,best_mask=inliers.sum(),H,inliers
    print(f"RANSAC: {max_inliers} inliers found")
    return best_H,best_mask
def stitch_images(img1,img2,H):
    h2,w2=img2.shape[:2]; h1,w1=img1.shape[:2]
    corners_img1=np.float32([[0,0],[0,h1],[w1,h1],[w1,0]]).reshape(-1,1,2)
    warped_corners=cv.perspectiveTransform(corners_img1,H)
    all_corners=np.vstack((warped_corners,np.float32([[0,0],[0,h2],[w2,h2],[w2,0]]).reshape(-1,1,2)))
    xmin,ymin=np.int32(all_corners.min(axis=0).ravel())
    xmax,ymax=np.int32(all_corners.max(axis=0).ravel())
    t=[-xmin,-ymin]
    H_translate=np.array([[1,0,t[0]],[0,1,t[1]],[0,0,1]])
    result=cv.warpPerspective(img1,H_translate@H,(xmax-xmin,ymax-ymin))
    result[t[1]:h2+t[1],t[0]:w2+t[0]]=img2
    return result
```



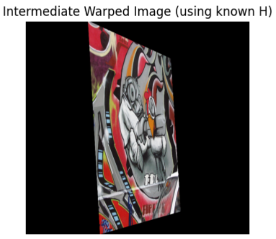
Inlier Matches After RANSAC



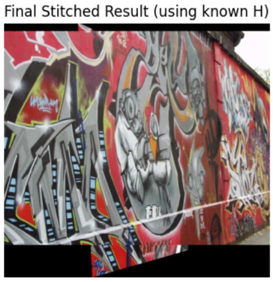
Stitched Result

Homography matrix used for stitching: $\begin{bmatrix} 0.2201 & -0.08589 & 334.0 \\ 0.06482 & 0.11898 & 347.0 \\ 1.3509 \times 10^{-4} & -1.8554 \times 10^{-4} & 1 \end{bmatrix}$

If the given Homography matrix is used, the following result is obtained:



Warped Source Image



Final Stitched Result