# Introduction to Computer Vision

## Assignment #2

Due: Nov.-15 (Fri.) (before 11:59pm)

### Instruction

a. Submit your source codes in a single compressed file "CV_A2_*StudentID*.zip" to iCampus.

b. Python 3.7 or higher / OpenCV 3.4 or higher will be used to execute your submitted codes.

c. In this assignment, you will take grayscale images as input. In order to open an image as grayscale, you can use the following statement:

```
img = cv2.imread( IMAGE_FILE_PATH , cv2.IMREAD_GRAYSCALE )
```

d. You can submit at most 4 python files. In other words, you can add 2 additional python files to implement functions commonly utilized across different parts.

e. Any work that you turn in should be your own.

### Part #1. 2D Transformations [40 pts]

The requirements of Part #1 will be evaluated by running '***A2_2d_transformations.py***' file.

1-1. Visualization of a transformed image on a 2D plane.

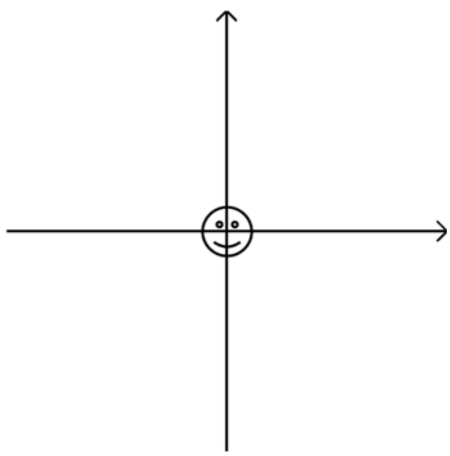
a) In Part #1, we will use '*smile.png*' as the input image. The image can be changed for evaluation, however, you can assume that the input image is odd sized along both dimensions.

b) Implement a function that returns a plane where the transformed image is displayed. The function gets two parameters, an image `img` and a $3 \times 3$ affine transformation matrix `M`. The vertical and horizontal sizes of the plane is fixed to $801 \times 801$ and the origin $(0,0)$ is corresponding to the pixel at $(400,400)$. You also need to draw two arrows to visualize $x$ and $y$ axes.

```
function plane = get_transformed_image ( img , M )
```

c) We initially place the image centered at the origin. Thus, the function should return the following plane if the matrix `M` describes the identity mapping:

$$M = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



d) To add arrows to the plane, you can use the built-in function `cv2.arrowedLine(...)`.

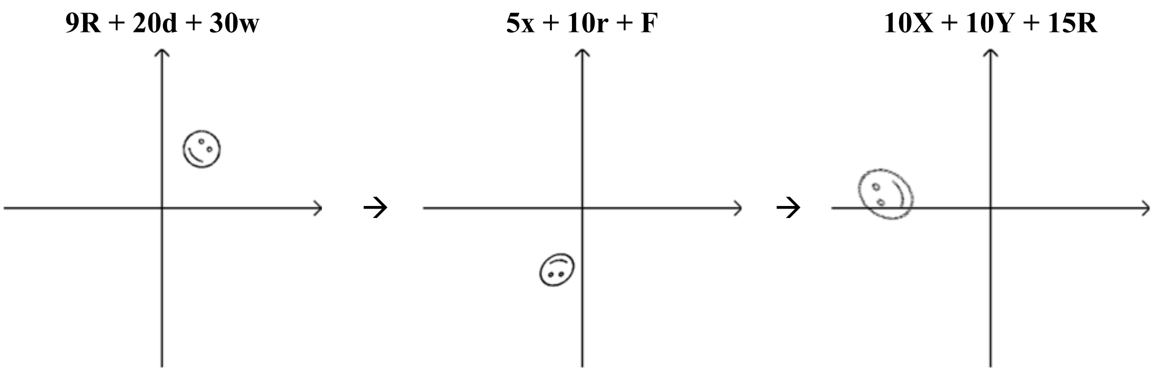
e) You cannot use any built-in function that directly performs image transformations.

1-2. Interactive 2D transformations

a) Implmenet your script to support interactions by a keyboard for various transformations of the image. The required actions are described as follows:

| Key | Action |
|---|---|
| ‘a’ | Move to the left by 5 pixels |
| ‘d’ | Move to the right by 5 pixels |
| ‘w’ | Move to the upward by 5 pixels |
| ‘s’ | Move to the downward by 5 pixels |
| ‘r’ | Rotate counter-clockwise by 5 degrees |
| ‘R’ | Rotate clockwise by 5 degrees |
| ‘f’ | Flip across $y$ axis |
| ‘F’ | Flip across $x$ axis |
| ‘x’ | Shirnk the size by 5% along to $x$ direction |
| ‘X’ | Enlarge the size by 5% along to $x$ direction |
| ‘y’ | Shirnk the size by 5% along to $y$ direction |
| ‘Y’ | Enlarge the size by 5% along to $y$ direction |
| ‘H’ | Restore to the initial state |
| ‘Q’ | Quit |

b) Refer the following examples:




c) You have to use the function implemented in 1-1.

d) **Extra credit**: We have some artifacts when we enlarge or rotate the image as shown in the above examples. Reducing the artifacts gets extra credits.

**Part #2. Homography [60 pts]**

The requirements of Part #2 will be evaluated by running ‘***A2_homography.py***’ file.

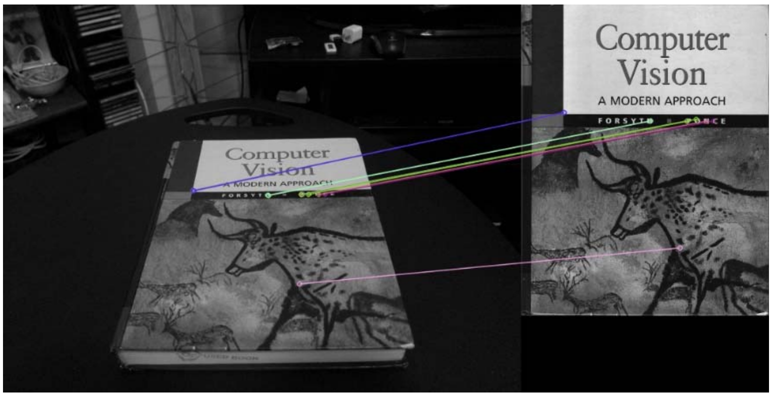
2-1. Feature detection, description, and matching

a) Read a pair of images.

b) Use the built-in functions to extract ORB (Oriented FAST and Rotated BRIEF) features from two images by referring the following code example:

```
orb = cv2.ORB_create()
kp = orb.detect( img , None )
kp, des = orb.compute( img , kp )
```

c) Perform feature matching between two images ('*cv_desk.png*' and '*cv_cover.jpg*'), and display top-10 matched pairs according to feature similarities. Note that, the similarities among ORB features should be computed by the Hamming distance.




d) You cannot use any built-in function that directly performs feature matching such as `BFMacher`. However, you can use `cv2.drawMatches(...)` to visualize the top-10 maches.

2-2. Computing homography with normalization

a) Implement a function that returns a homography from a source image to a destination image. The function gets two $N \times 2$ matrices, `srcP` and `destP`, where $N$ is the number of matched feature points and each row is a location in the image, and returns a $3 \times 3$ transformation matrix.

```
function H = compute_homography ( srcP , destP )
```

b) We first normalize feature points $x_S \in$ `srcP` based on the following steps:

1) Mean subtraction: translate the mean of the points to the origin $(0, 0)$

2) Scaling: scale the points so that the longest distance to the origin is $\sqrt{2}$

c) Perform 2-2-b) to $x_D \in$ `destP`. Since aforementioned normalization is a linear transformation, we can denote the transformations as two $3 \times 3$ matrices $T_S$ and $T_D$ for the `srcP` and `destP`, respectively. Then, we can write the normalized points as follows:

$$\widetilde{x_S} = T_S x_S \text{ and } \widetilde{x_D} = T_D x_D \quad \text{---- Eq (1)}$$

d) Once the points are normalized, compute the homography $H_N$ from $\widetilde{x_S}$ to $\widetilde{x_D}$ by referring the lecture slide (page #27 of *CV_06_Image_Homographies.pdf* ). Note that, you are allowed to use the built-in function, `numpy.linalg.svd(...)` to compute SVD.

e) Since the computed $H_N$ satisfied $\widetilde{x_D} = H_N \widetilde{x_S}$, we have $T_D x_D = H_N T_S x_S$ according to Eq (1). The transformation from `srcP` to `destP` is finally expressed as follows:

$$x_D = T_D^{-1} H_N T_S x_S$$

2-3. Computing homography with RANSAC

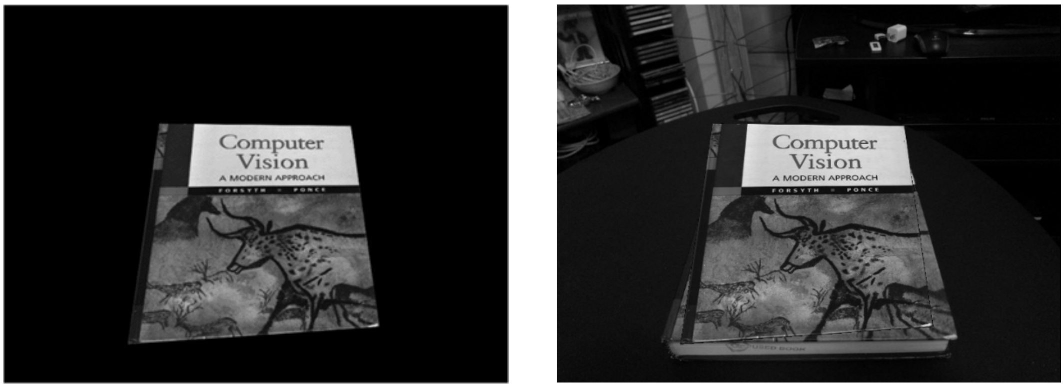
```
function H = compute_homography_ransac ( srcP , destP , th )
```

a) Implement a function that returns a homography with RANSAC by referring the lecture slide (page #39 of *CV_06_Image_Homographies.pdf* ). The parameter `th` is used to determine whether a point is inlier or outlier. You have to use the function implemented in 2-2.

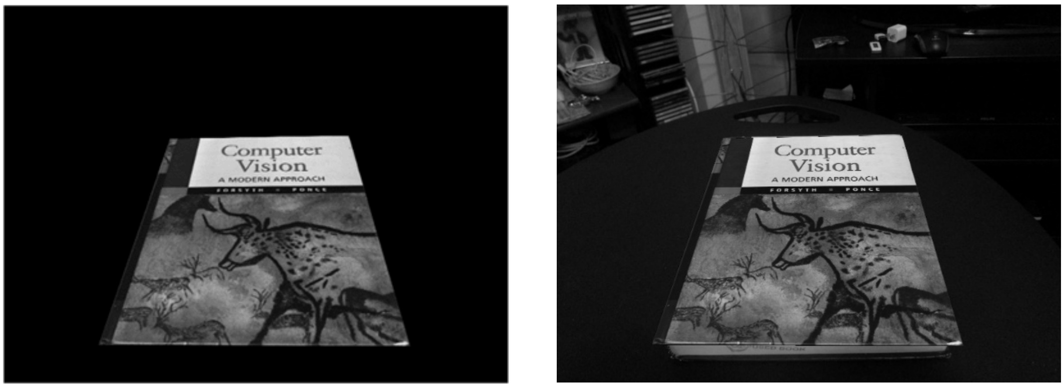
2-4. Image warping

a) Read '*cv_desk.png*' and '*cv_cover.jpg*', and compute homography from the cover image to the desk image.

b) Wraps '*cv_cover.jpg*' to the dimensions of '*cv_desk.png*'. Display the warpped image of '*cv_cover.jpg*' and the composed image. You can use `cv2.warpPerspective(...)` for the wrapping. Compare the results of the homography with normalization and ransac.

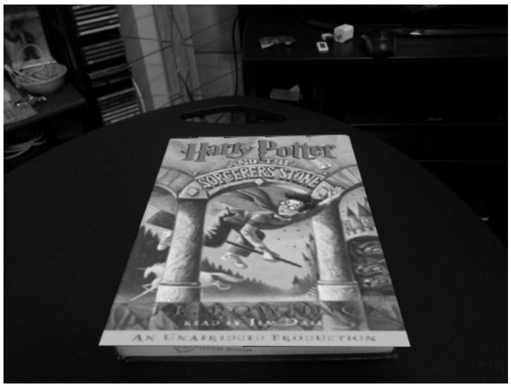


Homography with normalization



Homography with RANSAC

c) Wrap and compose '*hp_cover.jpg*' to '*cv_desk.png*' based on the homography with RANSAC computed in b), and display them.


2-5. Image stitching

a) Read '*diamondhead-10.png*' and '*diamondhead-11.png*', and stitch them based on the homography computed with RANSAC. Display the result.

b) In order to reduce the artifacts on the boundary of two images, perform a simple gradation based blending: