EECS 4422/5323
Lab 4: Panoramic Stitching

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Outline

This lab will involve an application of keypoint detection and descriptor matching.

- Problem Specification
- Keypoint Detection and Description
- Keypoint Matching
- Image Homography
- Stitching

Problem Specification

For now, we'll concentrate on the 2 image version of the problem. Given a left and right image with some overlap, the challenge is to take both images and stitch them together to make one large panoramic image.

You are provided with a set of images: three pairs of left and right images, and one pre-stitched output for one of the pairs (for comparison purposes).

Once you have a functioning stitching method, feel free to try taking your own pictures and stitching them!

Problem Specification

I_{ref}

I_{in}

$$I_{pano} = [I_{ref}, H \times I_{in}]$$

Keypoint Detection and Description

We discussed keypoint detection and description in class, so you should be familiar with the basic background for this step.

OpenCV has a number of tools for performing this operation. In particular, look at the class: `features2d`

As mentioned in class, a good starting point is ORB features, but there are a number of other features available. If you successfully get a pipeline functioning with ORB features, try swapping them out for other features to see how that affects your output.

Keypoint Matching

Once features are detected, you need to start matching features across images so you can perform *image registration*.

Keypoint matching is based on applying a distance metric over your descriptor space.

OpenCV provides two methods for feature matching: Flann and Brute-Force (BF).

Another function which may be useful is `drawMatches()`, which can help visualize the matches to provide a sanity check.

Basic 2D Transformations

Basic 2D transformations as 3x3 matrices

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Translate

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Scale

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\Theta & -\sin\Theta & 0 \\ \sin\Theta & \cos\Theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Rotate

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & sh_x & 0 \\ sh_y & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Shear

Affine Transformations

Affine transformations are combinations of:

- Linear transformations, and translations

$$\begin{bmatrix} x' \\ y' \\ w \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

Properties of affine transformations:

- Origin does not necessarily map to origin
- Lines map to lines
- Parallel lines remain parallel
- Ratios are preserved

Projective Transformations (Homography)

Projective transformations:

- Affine transformations, and projective warps

$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

Properties of projective transformations:

- Origin does not necessarily map to origin
- Lines map to lines
- Parallel lines do not necessarily remain parallel
- Ratios are not preserved

Image Homography

Once keypoints are matched, it is still necessary to compute the actual spatial transform which links the two images together. This is done by solving for the homography matrix H in the equation:

$$I_{in\_trans} = H \times I_{in}$$

Where I_{in_trans} is the transformed I_{in} w.r.t I_{ref} using the estimated H. You should understand this equation, and why RANSAC is an appropriate method for solving this correspondence.

Stitching

Once homography has been computed we need to warp the appropriate image by the homography matrix and then combine it with the non-warped image.

For further reading, there are a number of online tutorials which may provide helpful insights, suggestions, and code:

- Image Stitching Tutorial
- OpenCV panorama stitching