COMPUTER VISION ASSIGNMENT 2

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Part 1: Augmented Reality with Planar Homographies

1.1 Getting Correspondences

Load and Preprocess Images

- The book image is loaded in grayscale using OpenCV to prepare it for feature detection.
- The first frame of the video is extracted using `cv2.VideoCapture`.
- After extracting the frame, it is converted to grayscale as well, since feature detection methods like SIFT work on intensity values rather than color information.

Detect Keypoints and Compute Descriptors

- A SIFT (Scale-Invariant Feature Transform) detector is created using OpenCV's SIFT API.
- The `detectAndCompute` method is used to find keypoints and their corresponding descriptors in both the book image and the video frame.
- Keypoints represent distinctive locations in the image, and descriptors are numerical vectors that describe the region around each keypoint.

Match Descriptors Using Brute-Force Matcher

- A Brute-Force matcher is initialized to match descriptors between the two images.
- KNN (K-Nearest Neighbors) matching is used with `k=2`, which returns the two best matches for each descriptor from the book image.
- This provides a list of potential matches with varying degrees of similarity.

Apply Lowe's Ratio Test to Filter Matches

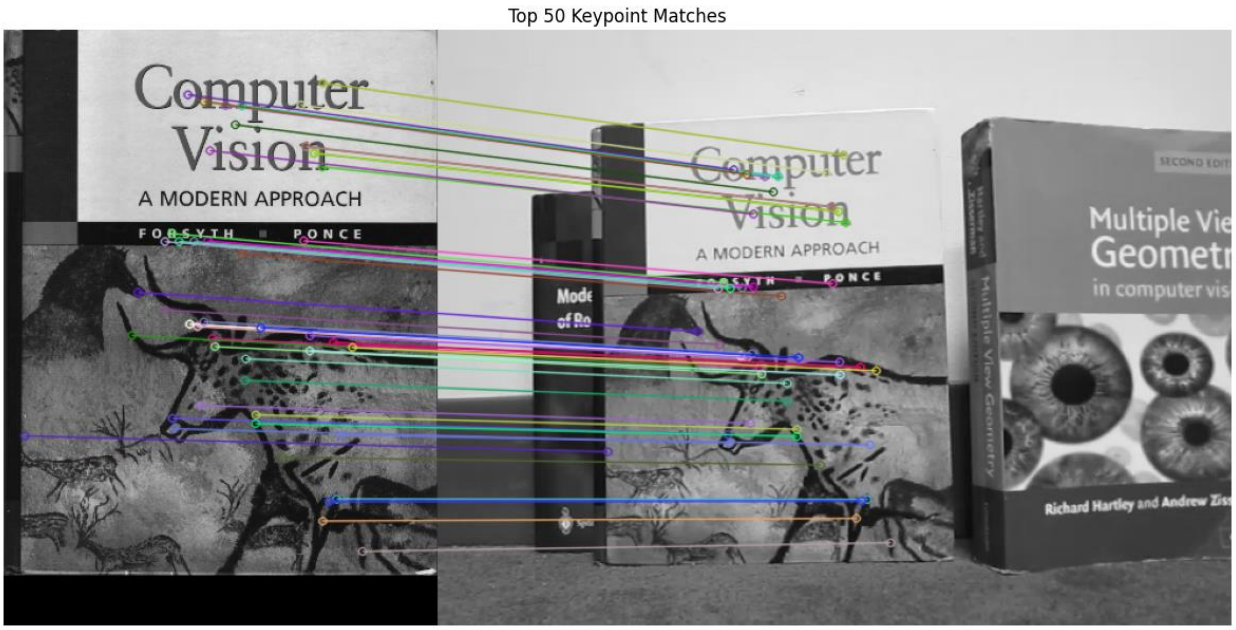
- Lowe's ratio test is applied to filter out weak or ambiguous matches.
- For each pair of matches `(m, n)`, the ratio of distances is calculated: `m.distance / n.distance`.
- If this ratio is less than 0.75, the match is considered good and added to the list of good matches.
- This step helps retain only the most confident and unique correspondences.

Select Top 50 Good Matches

- The list of good matches is sorted based on the distance between descriptors, where a smaller distance means a better match.
- The top 50 matches with the smallest distances are selected for visualization.
- This ensures that only the most accurate and relevant correspondences are used.

Draw and Display the Matches

- The selected matches are visualized by drawing lines between corresponding keypoints in the book image and the video frame.
- The cv2.drawMatches function is used to draw the top 50 matches.
- The result is displayed using a matplotlib plot, showing both images side by side with lines connecting matched keypoints.



1.2 Compute the Homography Parameters

Extract Keypoints and Descriptors

- Convert both images to grayscale.
- Use SIFT to detect keypoints and compute descriptors.

Match Descriptors

- Use Brute-Force Matcher with KNN (k=2).
- Apply Lowe's ratio test to keep good matches.

Estimate Homography (RANSAC)

- For a fixed number of iterations:
  - Randomly select 4 matching pairs.
  - Compute homography using least squares.
  - Apply homography to all points and calculate reprojection error.
  - Count inliers with error < threshold.
  - Keep the homography with the most inliers.

- Recompute final homography using all inliers.

Apply Homography

- Convert 2D points to homogeneous coordinates.
- Multiply by homography matrix.
- Convert back to 2D.

Interactive Point Mapping

- On mouse click in book image:
  - Transform point using H and draw on frame.
- On mouse click in frame:
  - Transform point using H^{-1} and draw on book.
- Display both images with drawn points.
- Exit on ESC key.

1.3 Calculate Book Coordinates

Initialize Variables

- Read the book image and video frames (book_cap, ar_cap).
- Extract keypoints and descriptors from the book image using SIFT.
- Define the corners of the book in the image (book_corners).

Set Up Video Writer

- Get frame properties (FPS, width, height) from the book video.
- Create a video writer for the output (output_overlay.mp4).

Process Each Frame

- Read frames from both the book and AR videos.
- Convert the book frame to grayscale and detect keypoints/descriptors.

Match Descriptors

- Use KNN to match descriptors between the book and video frame.
- Apply Lowe's ratio test to filter good matches.

Compute Homography

- If enough good matches exist, compute the homography matrix H using RANSAC.

Project Book Corners

- Apply homography H to the corners of the book to project them onto the video frame.

Overlay AR Frame onto Book

- Crop and resize the AR video frame to match the book image size.
- Warp the resized AR frame using the homography matrix.

Mask and Overlay

- Create a mask for the book region in the video frame.
- Use the mask to overlay the warped AR frame onto the book region in the video frame.

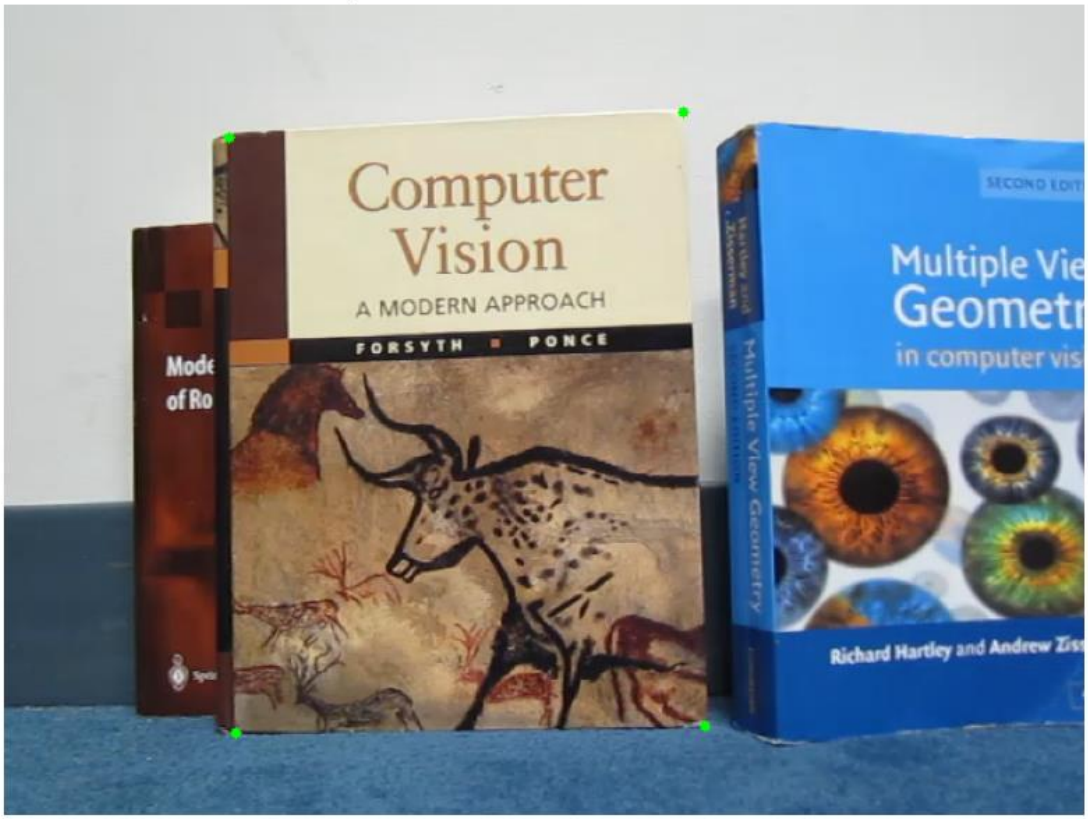
Write Output

- Write the resulting frame (with overlay) to the output video.
- Repeat for all frames.

Cleanup

- Release video captures and writer.

Projected Book Corners on Video Frame



Part 2: Image Mosaics

2.1 Getting Correspondences and Compute the Homography Parameters

Load Images

- Read the two images (pano_img1, pano_img2) in grayscale for SIFT processing.

Match Keypoints

- Initialize SIFT detector.
- Detect keypoints and compute descriptors for both images.
- Use brute-force matcher to find the best matches between descriptors.
- Apply Lowe's ratio test to filter out good matches.
- Select top n good matches.

Draw Matches

- Use OpenCV to draw the matches between the images.
- Display the result using matplotlib.

Compute Homography

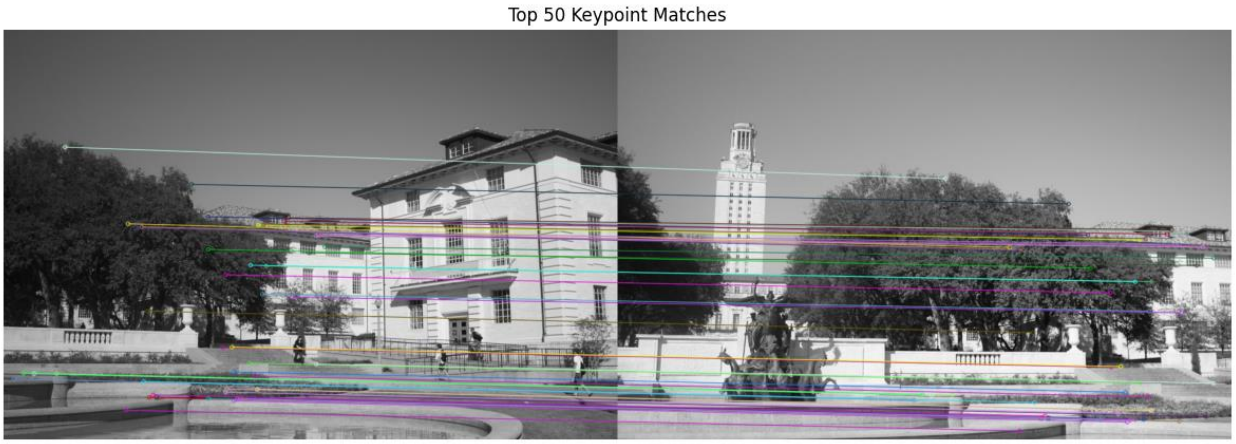
- Check if there are at least 4 good point correspondences.
- Set up a system of linear equations to solve for homography matrix H.
- Use least-squares to solve for the homography coefficients and reshape it into a 3x3 matrix.

Apply Homography

- Convert source points to homogeneous coordinates.
- Apply the homography matrix to the points using matrix multiplication.
- Convert the transformed points back to Cartesian coordinates.

Draw Projected Points

- Project points onto the original image using the computed homography.
- Optionally, draw actual points (from the previous matching step) on the image for comparison.
- Display the image with the projected and actual points.



2.2 Warping Between Image Planes & 2.3 Create the output mosaic

Warp Image Using Homography:

1. **Input**: Source image (src_img), homography matrix (H).
2. **Step 1**: Calculate the corners of the source image.
3. **Step 2**: Apply the homography to the corners to get the warped corners.
4. **Step 3**: Compute the bounding box of the warped corners.
5. **Step 4**: Compute the output image dimensions.
6. **Step 5**: Build a destination grid (output image).
7. **Step 6**: Compute the inverse homography (H_inv).
8. **Step 7**: Transform each point in the destination grid to the source image using inverse homography.
9. **Step 8**: Perform bilinear interpolation to sample pixel values from the source image and fill the destination image.
10. **Output**: Warped image.

Create Image Mosaic:

1. **Input**: Two images (image1, image2), homography matrix (H).
2. **Step 1**: Warp image1 using H.
3. **Step 2**: Compute the mosaic size based on both images.
4. **Step 3**: Apply translation to center the warped image on the mosaic.
5. **Step 4**: Warp image1 with the translated homography.
6. **Step 5**: Create a new canvas (mosaic).
7. **Step 6**: Overlay image1 and image2 onto the mosaic canvas.
8. **Output**: Final mosaic image

Bilinear Interpolation (for sampling pixels):

1. **Input**: Image, x-coordinates, y-coordinates.
2. **Step 1**: Identify valid coordinates within image bounds.
3. **Step 2**: For each valid coordinate, calculate the four neighboring pixels and interpolate based on the distances.
4. **Output**: Interpolated pixel values for the destination image.

Removing Black Pixels (from the final mosaic):

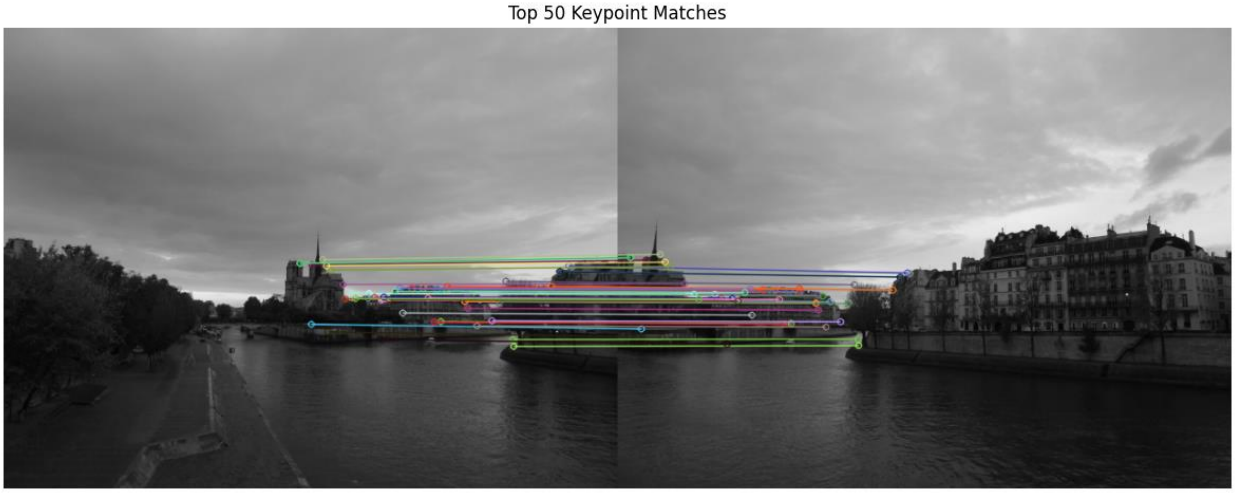
1. **Input**: Image.
2. **Step 1**: Identify rows and columns that are completely black.
3. **Step 2**: Delete those black rows and columns.
4. **Output**: Image without black borders.

Warped Image (Inverse Mapping)

Final Mosaic

Another Image of Our choice (same steps)

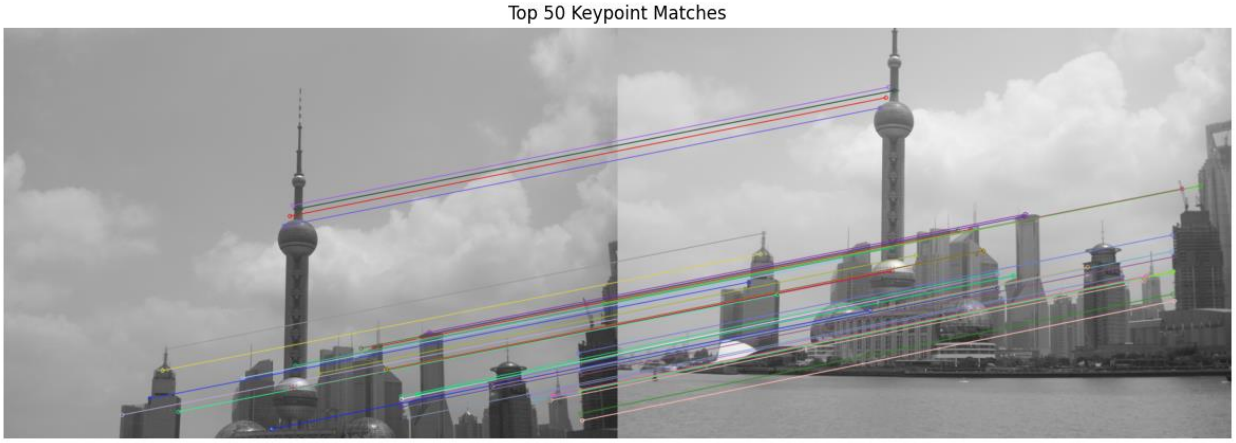
Top 50 Keypoint Matches



Final Mosaic

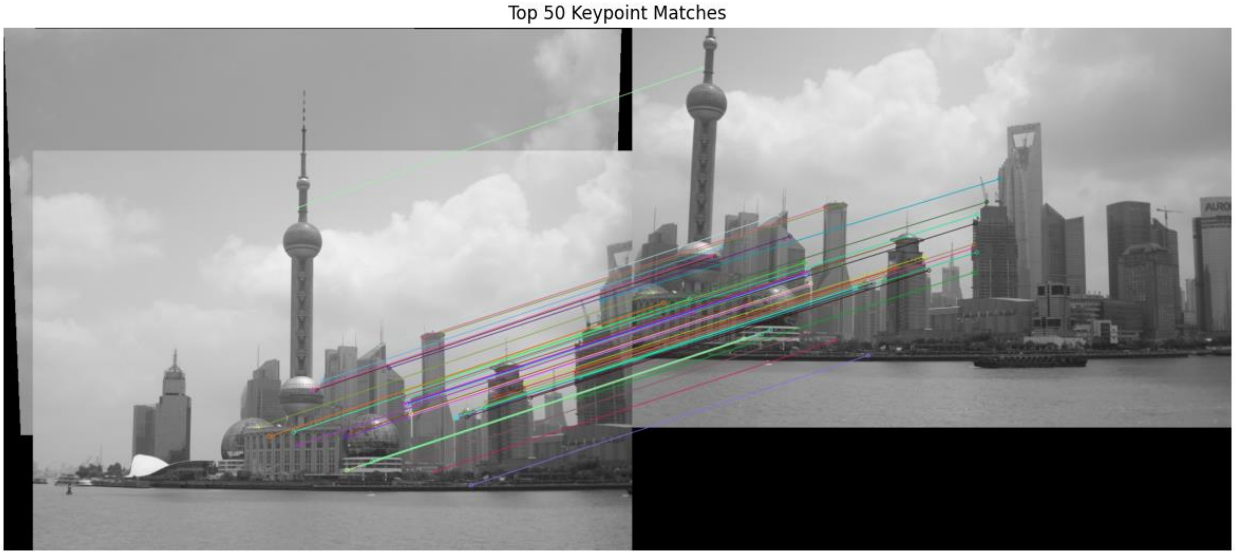
Part 3: Bonus

Top 50 Keypoint Matches



Final Mosaic

Top 50 Keypoint Matches



Final Mosaic