Image-Stitching using OpenCV

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Abstract

Image stitching is a core technique in computer vision used to generate a wide-field or panoramic view by combining multiple overlapping images. By detecting and matching keypoints across the input images and computing a homography transformation, the method aligns and blends images to produce a seamless composite. This project utilizes OpenCV's feature detection, homography estimation, and warping functions to achieve accurate image stitching.

Keywords: rendering, feature detection, matching keypoints, homography estimation, warping functions

1 Introduction

The need for wider field-of-view images in fields such as photography, surveillance, and mapping has led to the development of image stitching techniques. These techniques aim to automatically align multiple overlapping images and merge them into a single coherent output. Leveraging advancements in feature detection and transformation estimation, modern stitching methods provide robust and visually appealing results. The reference image is Figure 1

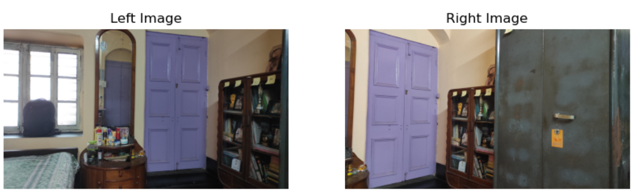

Figure 1: *Reference image*

The image stitching pipeline consists of the following key stages:

1. **Image Acquisition**: Two or more images with overlapping content are selected. These should share some common visual regions to ensure successful stitching.

2. **Feature Detection and Description**: Keypoints (distinctive visual patterns) are detected using algorithms like ORB or SIFT. Descriptors, which encode the appearance around each keypoint, are also computed.

3. **Feature Matching**: Descriptors from both images are compared to find matching keypoints. A matcher such as Brute-Force (BFMatcher) or FLANN is used. Matches are filtered based on distance ratio to improve robustness.

4. **Homography Estimation**: Using the matched points, a homography matrix (a perspective transformation) is calculated via RANSAC. This matrix aligns one image's plane onto the other.

5. **Image Warping and Blending**: One image is warped to align with the other using the computed homography.

6. **Image Stitching**: Images are then blended using simple techniques like overlay or linear blending to produce the stitched output.

2 Method Overview

1. Image Acquisition

Images with overlapping visual content are captured or selected. A sufficient overlap (typically 30–40%) is crucial to enable effective feature matching.

2. Feature Detection and Description

Distinctive keypoints are identified using algorithms such as ORB (Oriented FAST and Rotated BRIEF). ORB combines FAST for keypoint detection and BRIEF for descriptor computation. These descriptors encode the visual appearance around keypoints.

3. Feature Matching

Keypoints from both images are matched using descriptor similarity. Brute-Force Matcher (BFMatcher) compares each descriptor from one image to all descriptors from the other. The Hamming distance is used for binary descriptors. Lowe's ratio test filters matches using the criterion:

$$\frac{d(m)}{d(n)} < 0.75$$

where m and n are the best and second-best matches respectively. As shown in Figure 2, the feature matches have been successfully rendered.

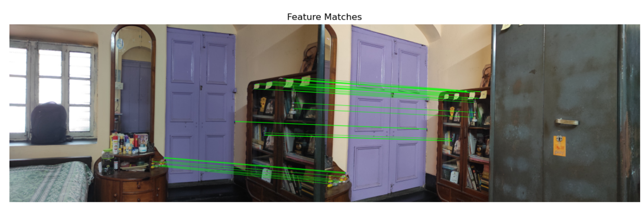

Figure 2: *Feature Matches*

4. Homography Estimation

Using matched keypoints, a homography matrix H is computed to model the transformation between two images:

$$p' = H \cdot p$$

where p and p' are corresponding points and H =

$$\begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

RANSAC is employed to estimate H robustly by handling outliers.

5. Image Warping and Blending

The first image is warped using the homography matrix to align with the second image:

$$\begin{bmatrix} x' \\ y' \\ w' \end{bmatrix} = H \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \Rightarrow (x', y') = \left(\frac{x'}{w'}, \frac{y'}{w'} \right)$$

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The warped image is then blended with the second image to form a stitched panorama using simple overlay or pixel-wise blending techniques. As shown in Figure 3, the image warping has been successfully rendered.

Figure 3: *Warped Image*

3 Results

The image stitching algorithm successfully aligned and merged the input images to generate a seamless panoramic output. Keypoints were detected and matched using feature descriptors (e.g., ORB or SIFT), and robust matching was ensured using RANSAC to estimate a homography between image pairs.

As shown in Figure 4, the overlapping regions were accurately aligned, and the transition between the images is smooth with minimal ghosting or distortion. This demonstrates the effectiveness of feature-based stitching in producing high-quality panoramas even with varying viewpoints and lighting conditions.

Figure 4: *Stitched Image*