Bosch AutoVisionX

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---------- Our Solution To the Given Problem ----------

Below are The given four input Images -

Expected or the Target Result that We needed to produce –

The best result achieved by our solution –

Our Approach –

Introduction

- Image stitching is a sophisticated computer vision technique that aims to create panoramic images by seamlessly blending multiple input images. It involves several key steps, including feature detection, feature matching, camera parameter estimation, image warping, exposure compensation, seam finding, blending, and result generation.

Feature Detection and Description

- **Feature Detection**: Features are distinctive points or regions in an image that can be reliably detected across different views. This algorithm employs various feature detection methods such as **AKAZE**, **SIFT (Scale-Invariant Feature Transform)**, **SURF (Speeded-Up Robust**

Features), and **ORB (Oriented FAST and Rotated BRIEF)**. These methods excel at identifying keypoints that are invariant to scale, rotation, and illumination changes.

- **Feature Description**: Once keypoints are detected, descriptors are computed to characterize their local neighborhoods. Descriptors encode information about the keypoints' appearance, enabling robust matching across images. This step is crucial for accurate feature matching.

Feature Matching

- **Algorithm Used**: Pairwise matching algorithms are employed to find correspondences between keypoints in different images. The algorithm utilizes techniques such as **BestOf2NearestMatcher** and **AffineBestOf2NearestMatcher**. These algorithms select the best matches based on distance metrics calculated from feature descriptors. Additionally, the matching process is guided by homography estimation to ensure accurate alignment.

Camera Parameter Estimation

- **Algorithm Used**: Camera parameters, including intrinsic and extrinsic parameters, are estimated to model the transformation between the images and the scene. This implementation utilizes homography-based or affine-based estimation techniques. These methods determine the optimal transformation matrix that aligns keypoints across images, providing essential information for subsequent processing steps.
- **Bundle Adjustment**: To refine the initial estimates of camera parameters, bundle adjustment techniques are applied. Bundle adjustment optimizes the parameters iteratively to minimize the reprojection error between matched keypoints. This refinement process enhances the accuracy of the camera parameter estimation.

Image Warping

- **Algorithm Used**: Images are warped based on the estimated camera parameters to align them geometrically for seamless stitching. Various warping methods such as plane, cylindrical, and spherical are supported to correct perspective distortion and ensure proper alignment. This step plays a crucial role in preparing the images for blending.

Exposure Compensation

- Exposure differences among input images can result in visible seams in the stitched panorama. Exposure compensation techniques are employed to adjust the pixel intensities in each image, ensuring consistent brightness across the panorama. This compensation step minimizes visual artifacts and enhances the overall quality of the panorama.

Seam Finding and Blending

- **Algorithm Used**: Seam finding algorithms such as **GraphCut** with color constraints are utilized to identify optimal seam locations where images are stitched together. These algorithms analyze image gradients and pixel intensities to determine smooth transition regions between images.
- **Blending Techniques**: Different blending techniques such as **multi-band blending** are applied to seamlessly merge images along the identified seams. Multi-band blending leverages multiple frequency bands to blend images gradually, resulting in natural-looking transitions without visible artefacts.

Result Generation

- The final panoramic image is generated by combining the warped and blended images. The resulting panorama provides a comprehensive view of the scene captured by the input images, seamlessly integrating them into a single cohesive image.

Logging and Error Handling

- Throughout the algorithm execution, logging messages are used to provide detailed feedback on the progress and timings of different stages. These messages aid in monitoring the algorithm's performance and diagnosing potential issues.
- Robust error handling mechanisms are implemented to manage exceptions and errors that may arise during critical operations. Error handling ensures the algorithm's reliability and resilience to unexpected conditions.

- **Conclusion**

Image stitching algorithms represent a culmination of advanced computer vision techniques, combining feature detection, matching, camera parameter estimation, warping, exposure compensation, seam finding, blending, and result generation. By leveraging these techniques, these algorithms produce high-fidelity panoramas that faithfully capture the entire scene depicted in the input images.

Our parameters that best produced the Results –

```
./sol.exe img1.jpg img2.jpg img3.jpg img4.jpg --features sift --matcher homography --estimator homography --match_conf 0.6 --wave_correct horiz --seam gc_color --blend multiband --blend_strength 20  --work_megapix 6 --seam_megapix 0.5
```

1. **Input Images**
    - **img1.jpg**, **img2.jpg**, **img3.jpg**, **img4.jpg**: These are the input images to be stitched together to create a panorama.
2. **Feature Detection and Description**
    - **--features sift**: Specifies that the SIFT (Scale-Invariant Feature Transform) algorithm should be used for feature detection and description. SIFT is chosen for its robustness to scale, rotation, and illumination changes, making it suitable for matching keypoints across different views.
3. **Feature Matching**
    - **--matcher homography**: Selects the homography-based matcher for pairwise image matching. The homography matcher is well-suited for aligning images with planar scenes, providing accurate correspondences between keypoints.
4. **Camera Parameter Estimation**

- **--estimator homography**: Indicates that the homography transformation estimator should be used to estimate camera parameters. Homography estimation is appropriate when the scene can be approximated as planar, as it provides a mapping between image coordinates and scene coordinates.

5. **Feature Matching Confidence**

    - **--match_conf 0.6**: Sets the confidence threshold for feature matching to 0.6. This value determines the level of confidence required for a feature match to be considered valid, helping to filter out unreliable matches and improve the accuracy of alignment.

6. **Wave Effect Correction**

    - **--wave_correct horiz**: Specifies horizontal wave effect correction. This correction mitigates distortions caused by parallax effects, ensuring smooth transitions between adjacent images along the horizontal axis.

7. **Seam Estimation**

    - **--seam gc_color**: Utilizes the GraphCut algorithm with color constraints for seam estimation. GraphCut is employed to find optimal seam locations with minimal visual artefacts, enhancing the quality of the stitched panorama.

8. **Blending**

    - **--blend multiband**: Chooses the multi-band blending method for seamlessly merging images along the identified seams. Multi-band blending effectively combines image regions at different frequencies, producing natural-looking transitions without visible artefacts.

9. **Blending Strength**

    - **--blend_strength 20**: Sets the blending strength to 20, controlling the intensity of blending applied during the stitching process. Adjusting this parameter helps achieve the desired balance between image fusion and preserving fine details.

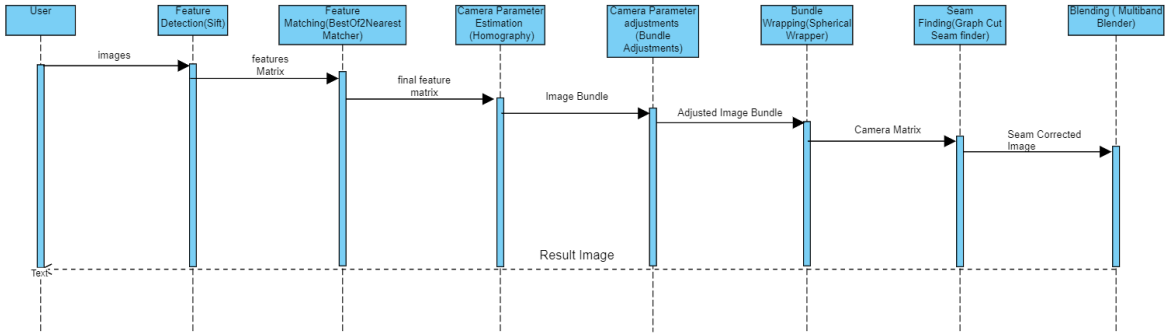
10. **Image Registration Resolution**

    - **--work_megapix 6**: Specifies a resolution of 6 megapixels for the image registration step. This resolution determines the level of detail considered during feature matching and camera parameter estimation, balancing computational efficiency with accuracy.

11. **Seam Estimation Resolution**

    - **--seam_megapix 0.5**: Sets a resolution of 0.5 megapixels for the seam estimation step. This resolution influences the precision of seam localization, ensuring smooth transitions between images while minimizing computational overhead.

12. Sequence Diagram to visualize codeflow

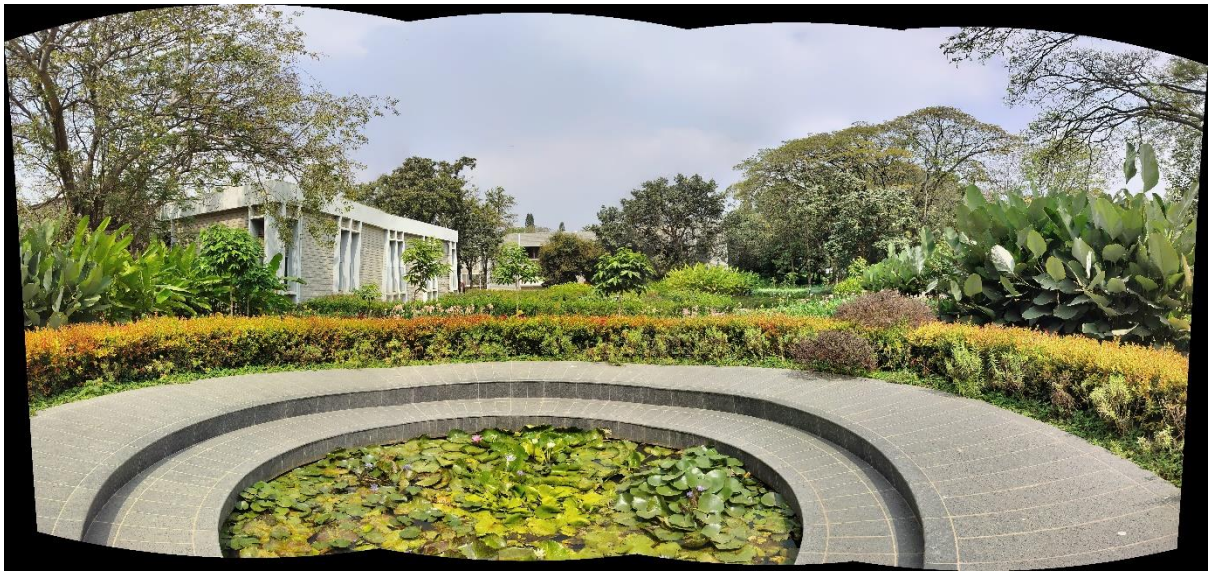


Due to the Specified parameters it takes on an average of 25-30 secs to produce the result Image. The speed can be improvised with - - try_cuda Flag which utilizes gpu power if feature finding thresholds are increased or the increase in the number of images or for greater amount of processing.

Parameter that will produce faster result but compromises the stitching –

```
./sol.exe img1.jpg img2.jpg img3.jpg img4.jpg --features sift --matcher homography --estimator homography --match_conf 0.4 --wave_correct horiz --seam gc_color --blend multiband --blend_strength 20
```

Here by default 1 megapixel is set for the image registration step. This resolution determines the level of detail considered during feature matching and camera parameter estimation, balancing computational efficiency hence producing faster result.



Thank You ✌

Note: For code building and execution refer the “Build&Run_Guide.pdf” in this same zip folder.