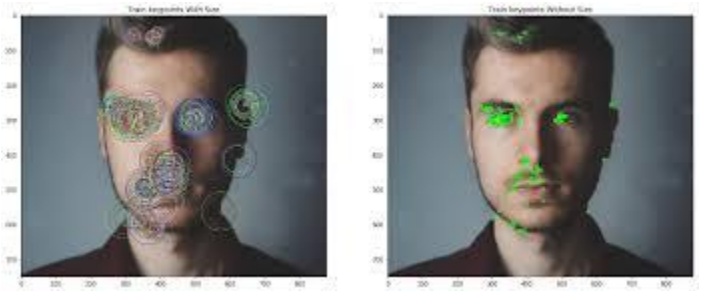
Feature Detection & Feature Matching

Individual Project 02 - S19355

1. Introduction

Feature detection and matching are fundamental techniques in computer vision used to identify and compare important regions (features) in images. These techniques are widely used in image recognition, object tracking, panorama stitching, and 3D reconstruction.

1. Feature Detection - Identifies distinct and repeatable points in an image (such as edges, corners, or blobs) that are invariant to scale, rotation, and illumination changes.



2. Feature Matching - Compares features between two or more images to find correspondences, allowing tasks like object tracking or image stitching.

2. Harris Corner Detection

Harris Corner Detection is a well-known algorithm used to detect corners in an image. It was introduced by **Chris Harris and Mike Stephens** in 1988 as an improvement over earlier corner detection methods.

Key Points of Harris Corner Detection :

- Mathematical Approach - Based on autocorrelation function that measures local intensity variations.
- Corner Response Function - Uses the matrix M to analyze intensity changes and compute a response function:

$$R = \det(M) - k(\text{trace}(M))^2$$

- Detects Corners Efficiently - Identifies regions where intensity varies significantly in multiple directions.
- Robust but Lacks Scale/Rotation Invariance - Works well but does not handle scale changes or rotation effectively.
- Improvements - Can be enhanced using Gaussian filtering, adaptive thresholding, and sub-pixel accuracy (cv.cornerSubPix).

3. Implementations, Results & Discussion

A. Pure Harris Corner Detection Algorithm [Figure 1 & Figure 2]

The pure Harris corner detection method successfully identifies most of the corners in an image because it relies on detecting regions with high-intensity variations in multiple directions. The following points justify its performance,

1. *Effective Detection of Corners*
    - The algorithm computes the corner response function using the structure tensor matrix, which allows it to detect true corners effectively.
    - Most sharp intersection points (like chessboard corners) are detected.

2. *Sensitivity to Noise and Non-Maximum Suppression Issues*
    - The raw Harris detector lacks adaptive thresholding and non-maximum suppression, which means some weak corners might be suppressed while some strong non-corner points may be misidentified.
    - Noisy edges and textured regions sometimes get detected as corners due to intensity variations.

3. *Lack of Sub-Pixel Accuracy*
    - Detected corners are not refined beyond integer pixel locations, leading to slightly inaccurate positioning in some cases.
    - The method does not perform local refinement, so detected corners may shift slightly from the true corner locations.

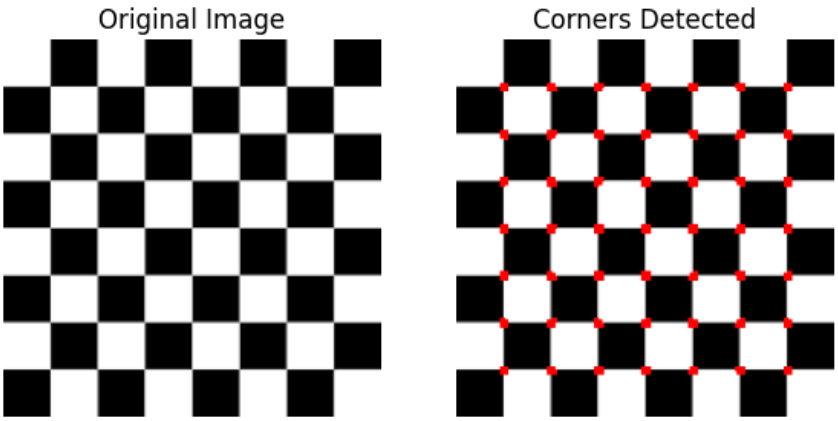
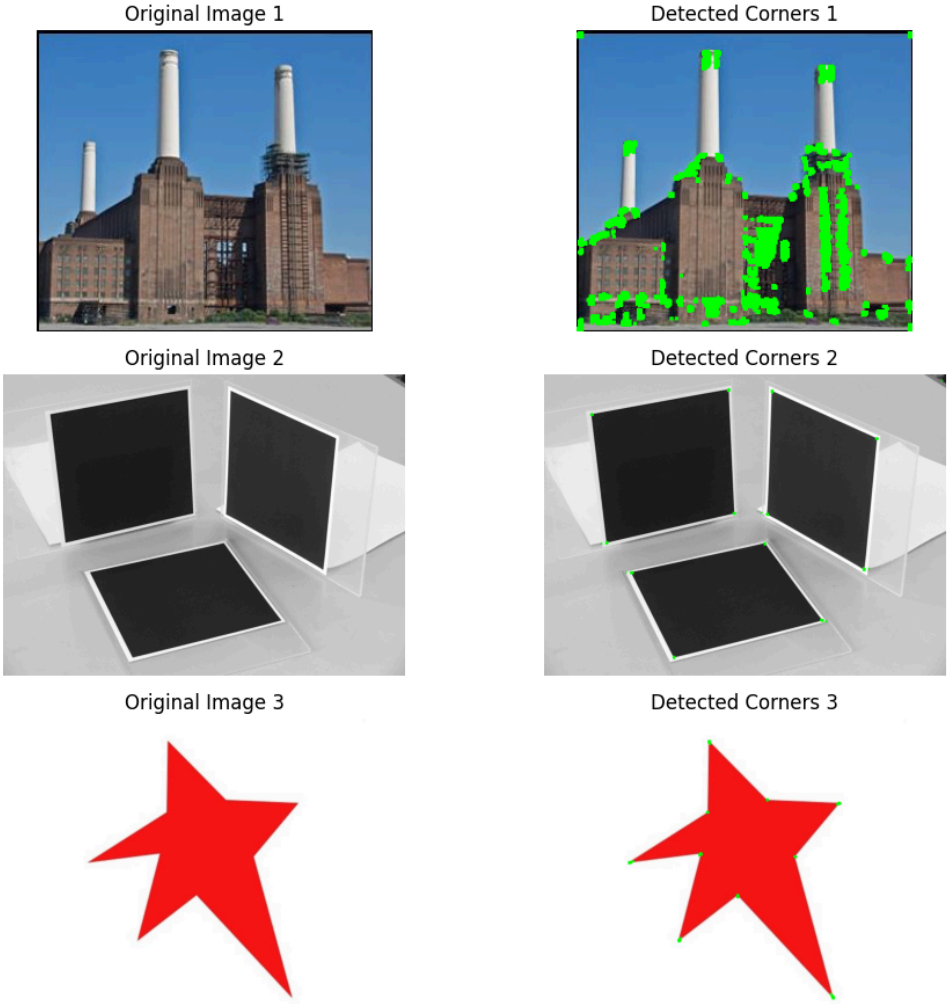


Figure 1: Result of Pure Harris Implementation for a Checker Board



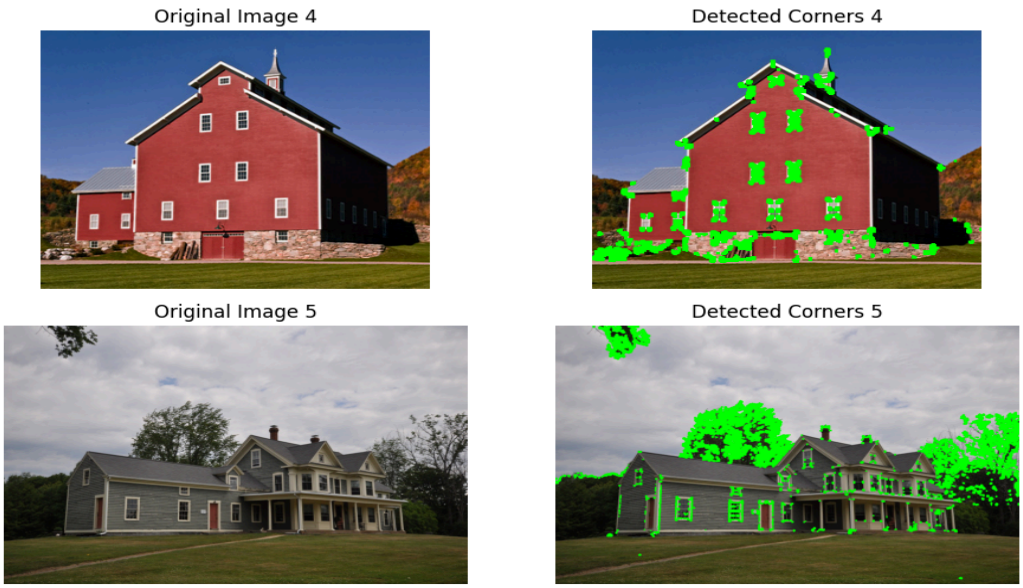


Figure 2: Pure Implementation Testing for Several Images

B. Enhanced Harris Corner Detection Algorithm [Figure 3]

The enhanced Harris corner detection method improves upon the pure version using three key modifications,

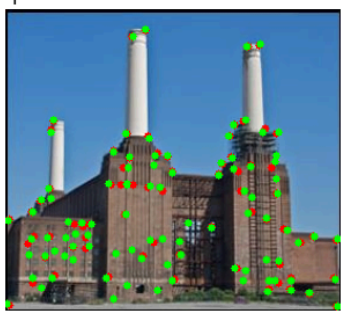
1. *Improved Preprocessing*
    - Gaussian Blur: Reduces noise and eliminates false detections caused by random intensity fluctuations.
    - Histogram Equalization: Improves contrast, enhancing edge clarity and making corner detection more reliable.

2. *Adjusted Harris Parameters*
    - Block size, aperture size, and k values are fine-tuned to achieve a better balance between detection sensitivity and suppression of false positives.
    - Non-maximum suppression ensures that only the strongest corner responses are retained, reducing redundant detections.

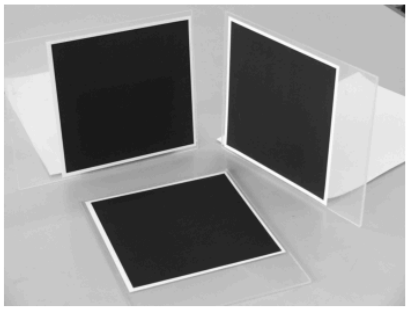
3. *Sub-Pixel Accuracy Refinement*
    - cv.cornerSubPix() refines the corner locations to sub-pixel precision using an iterative process based on intensity changes.
    - This ensures that the detected corners align more accurately with the true geometric corners, preventing small shifts in detection.

Original Image 1

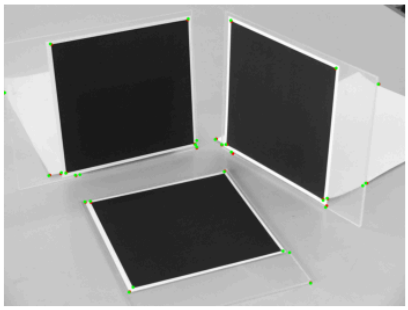
Optimized Harris Corner Detection 1



Original Image 2



Optimized Harris Corner Detection 2



Original Image 3

Optimized Harris Corner Detection 3

Original Image 4

Optimized Harris Corner Detection 4

Original Image 5

Optimized Harris Corner Detection 5

Figure 3: Improved Algorithm Testing for Same Images

4. Conclusion

The pure Harris corner detection method effectively detects most corners but suffers from noise sensitivity and lacks precise localization. By incorporating image preprocessing, parameter tuning, and sub-pixel refinement using cv.cornerSubPix(), the enhanced version significantly improves detection accuracy. This optimized approach ensures more precise, noise-resistant, and reliable corner detection, making it superior for applications requiring high-precision feature extraction.

5. References

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