Assignment 3

Ali Yeşilkanat - 2017700159

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1 Introduction

In this task, SIFT and Harris interest point detectors are compared with respect to repeatability measure. Different conditions such as JPEG compression quality, homography transformation and noise are used to calculate repeatability measure. For generating images with different noise levels and jpeg qualities PIL library is used, for SIFT and Harris OpenCV library is used and also a Harris Corner Detector is implemented in this work.

2 Data Preparation

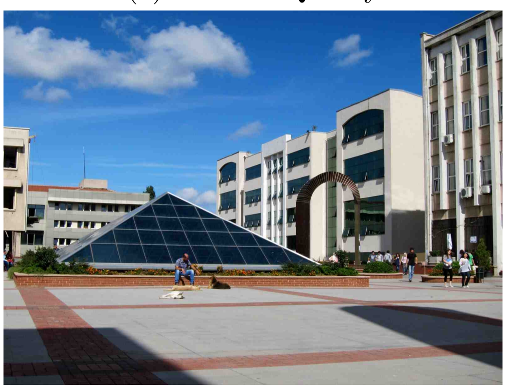
2.1 Producing Images of Different JPEG Qualities

Given "kuzey.jpg" image, using PIL framework, different quality of JPEG compression applied.

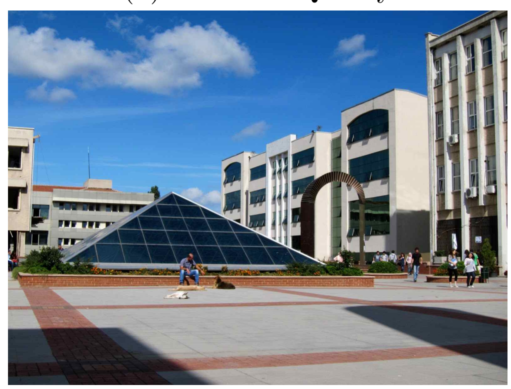
Figure 1: kuzey.jpg.

(a) 0 JPEG Quality

(b) 20 JPEG Quality



(c) 40 JPEG Quality



(d) 60 JPEG Quality

(e) 80 JPEG Quality

(f) 100 JPEG Quality

Figure 2: kuzey.jpg variations on different JPEG qualities.

2.2 Adding Gaussian Noise

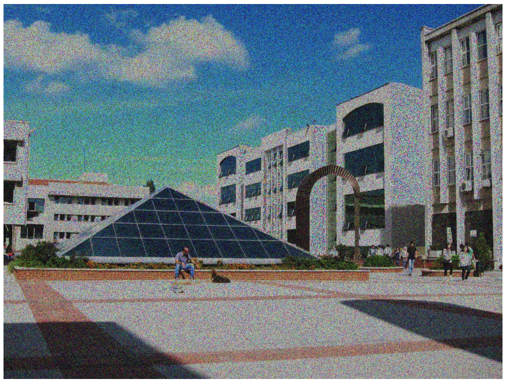
Using

$$X \sim \mathcal{N}(0,\, \sigma^2)\,.$$

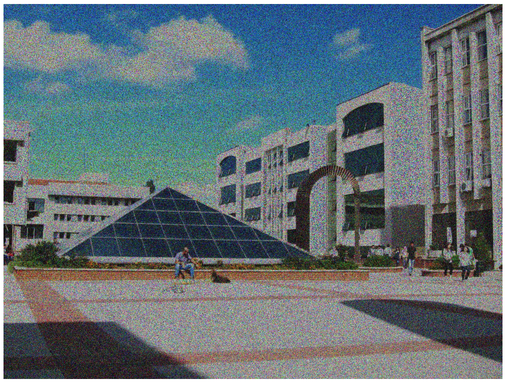
distribution, 6 different images with different noise levels are created. Variances are selected as 1000,2000,3000,4000,5000,6000 and later on noisy images are clipped between 0-256 RGB scale.

(a) Level 1 Noise

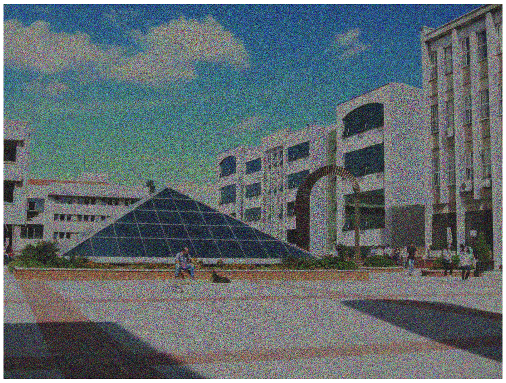
(b) Level 2 Noise



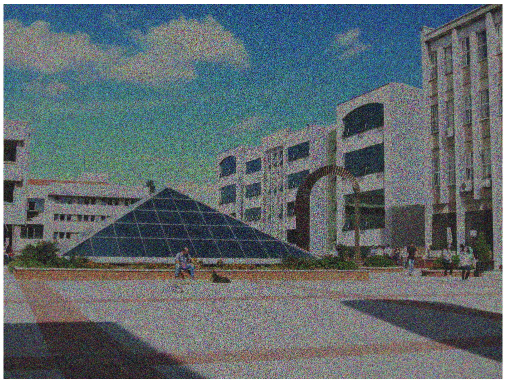
(c) Level 3 Noise



(d) Level 4 Noise



(e) Level 5 Noise



(f) Level 6 Noise

Figure 3: Noisy kuzey.jpg images with different Gaussian noise levels.

3 Implementing Harris Corner Detector

First derivatives of image on both x and y directions are computed by Gaussian Filters with 0.5 .

$$M = \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

Later on the smallest eigenvalue of the structure tensor is computed with following approximation equation.

$$\lambda_{min} \approx \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2} = \frac{det(M)}{trace(M)}$$

is calculated as Harris response. Then, candidate values are sorted by response value and used as key points with calculated threshold.

4 Measuring Repeatability

4.1 Repeatability Calculation

Repeatability is defined as:

$$r_i(\epsilon) = \frac{\mid R_i(\epsilon) \mid}{min(n_i, n_j)}$$

where $R_i(\epsilon)$ denotes a set of point pairs $(\tilde{x}_i, \tilde{x}_j)$ laying in an $\epsilon-$ neighbourhood:

$$R_i(\epsilon) = \{(\tilde{x}_i, \tilde{x}_j) \mid dist(\tilde{x}_i, \tilde{x}_j) < \epsilon\}$$

In this work neighbouring defined as, two different key points are checked as same or not by a imaginary rectangular having 4x4 pixels. Repeatability is calculated between first image in all extracted images and the other images.

4.2 JPEG Quality Repeatability Comparison

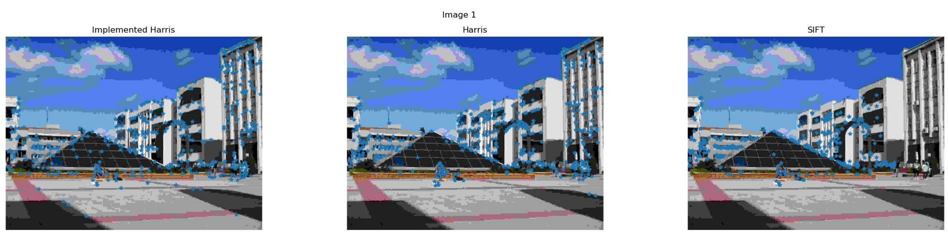


Figure 4: Quality 0 Image

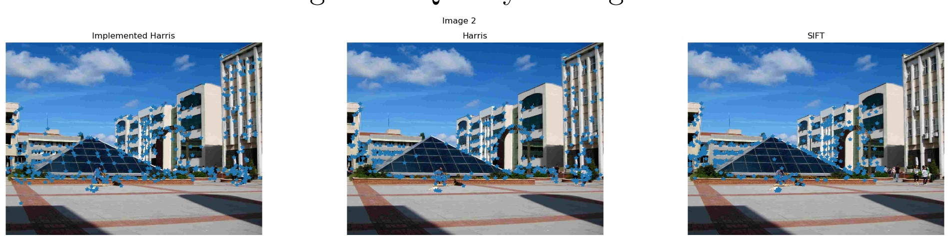


Figure 5: Quality 20 Image

Figure 6: Quality 40 Image

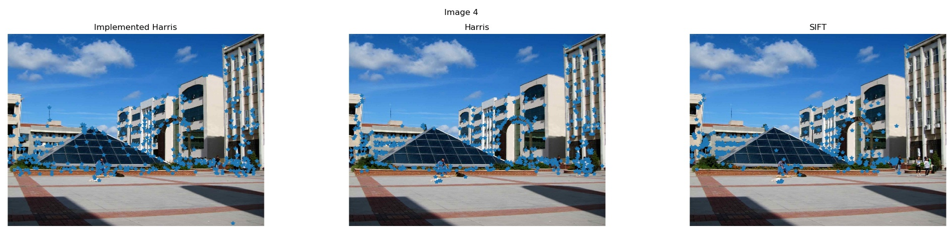


Figure 7: Quality 60 Image

Figure 8: Quality 80 Image

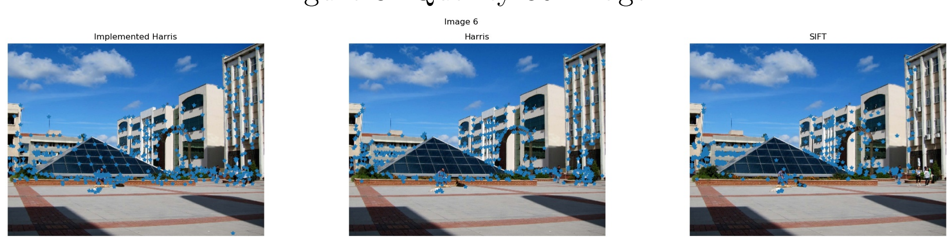


Figure 9: Quality 100 Image

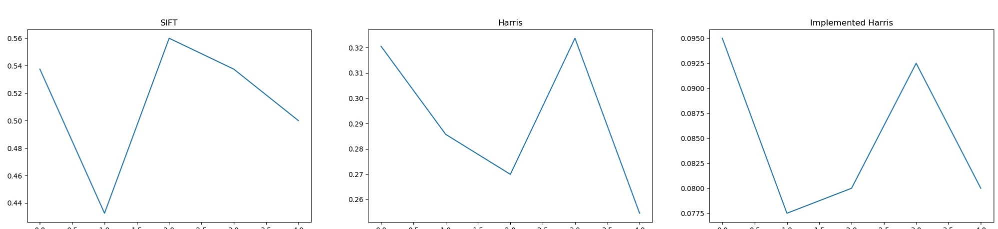


Figure 10: Repeatability on different Quality Conditions.

4.3 Gaussian Noisy Repeatability Comparison

Figure 11: Noise Level 1 Image

Figure 12: Noise Level 2 Image

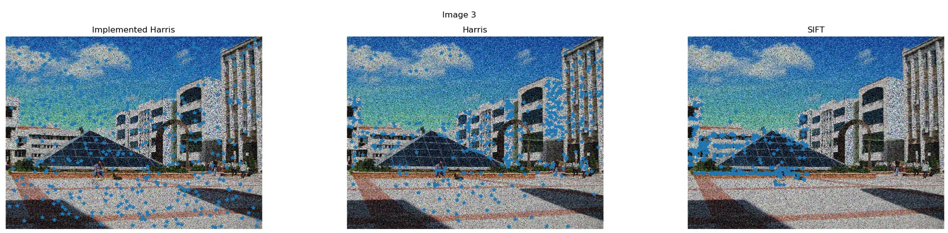


Figure 13: Noise Level 3 Image

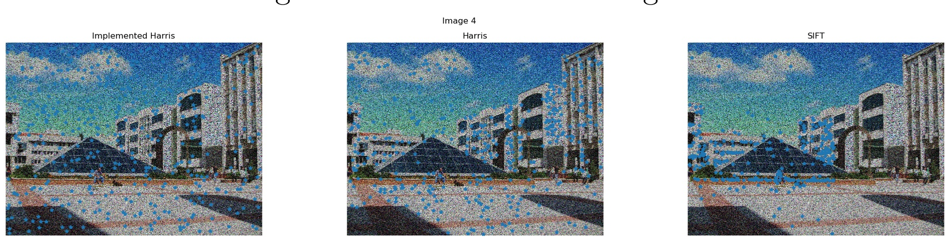


Figure 14: Noise Level 4 Image

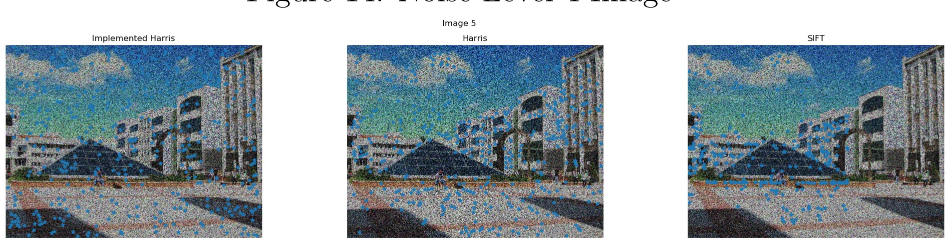


Figure 15: Noise Level 5 Image

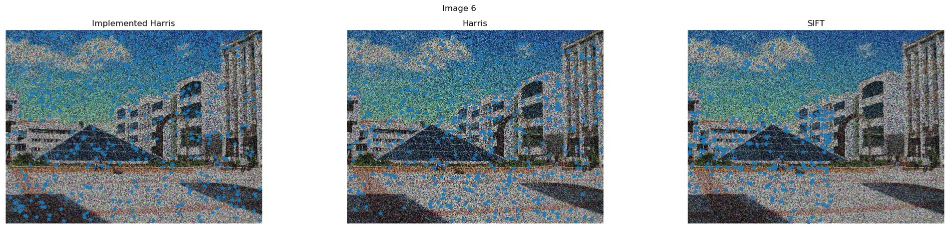


Figure 16: Noise Level 6 Image

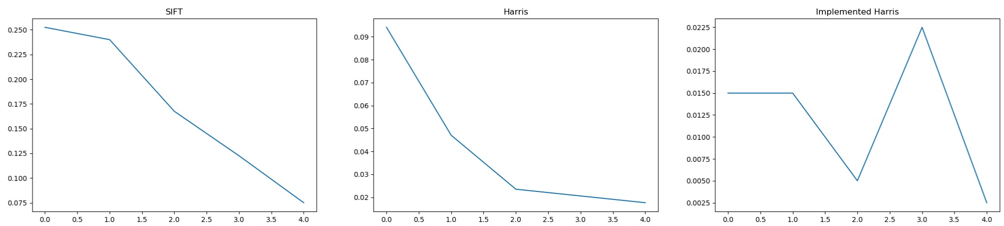


Figure 17: Repeatability on different noise levels.

4.4 Repeatability on Homography Transformation

By using homography matrixes given with the images, detected key points (x, y) on the first images are transformed using equation:

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

Figure 18: Keypoints on Image 1

Figure 19: Keypoints on Image 2

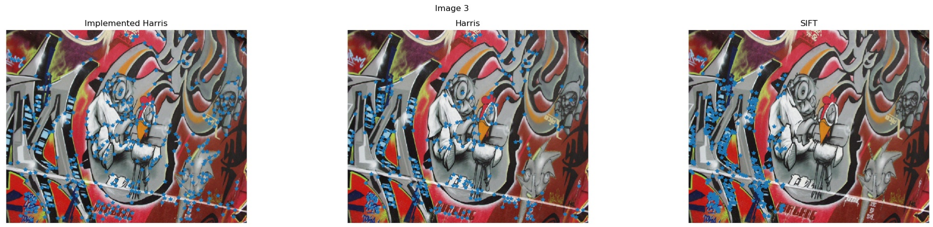


Figure 20: Keypoints on Image 3

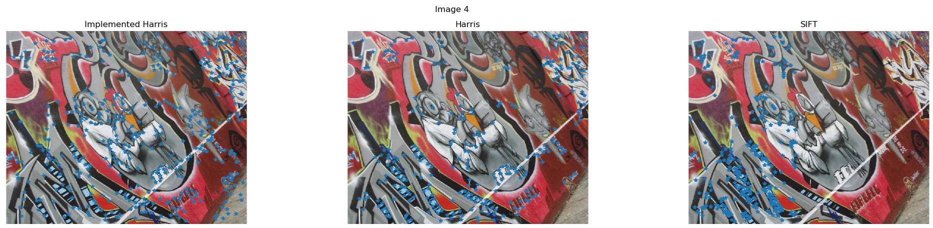


Figure 21: Keypoints on Image 4

Figure 22: Keypoints on Image 5

Figure 23: Keypoints on Image 6

Using given homography matrices, detected key points are transformed into new image coordinates (see 4.4).

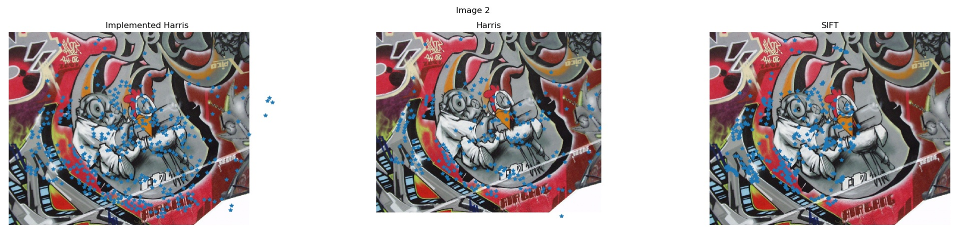


Figure 24: Transformation to $2^n d$ image.

Figure 25: Transformation to $3^r d$ image.

Figure 26: Transformation to $4^t h$ image.

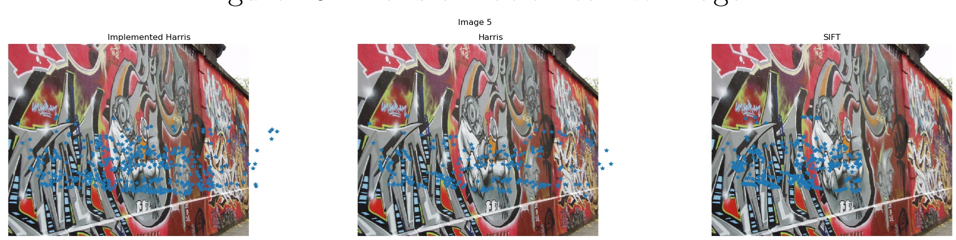


Figure 27: Transformation to $5^t h$ image.

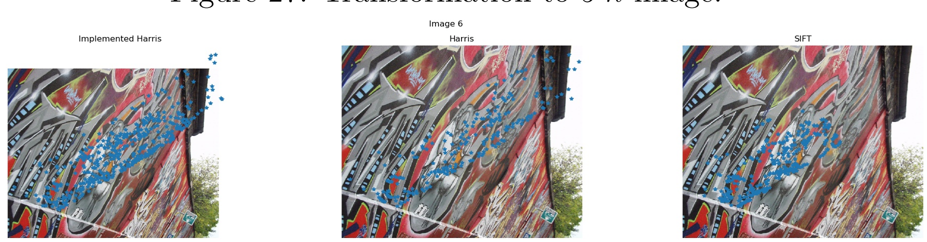


Figure 28: Transformation to $6^t h$ image.

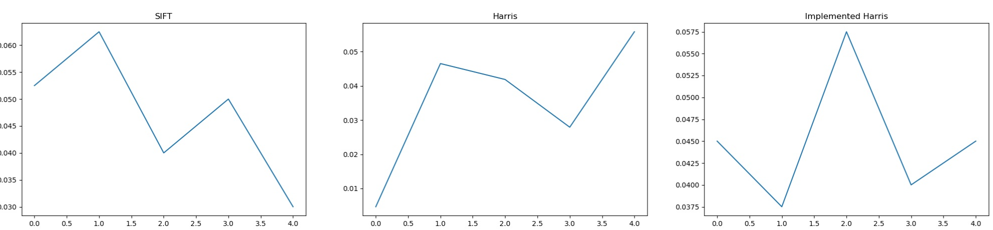


Figure 29: Repeatability