

# A Comprehensive Report on PCA

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## 1 ALL IMAGES DATASET

[Task 1 Video]

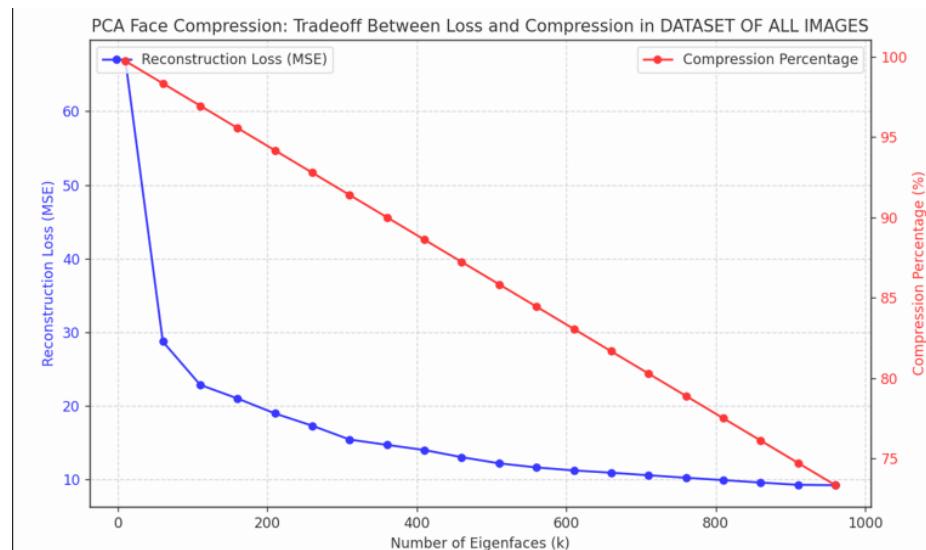


Figure 1: Eigenfaces Visualization

Table 1: Face Position Reconstruction Analysis

|             | Straight | Left | Right  | Half Face Covered |
|-------------|----------|------|--------|-------------------|
| Cost        | 31       | 24   | 30.83  | 28                |
| Compression |          |      | 80.78% |                   |

### 1.1 Reconstruction Loss Analysis

Initially, the reconstruction loss is very high when using only a few eigenfaces (low  $k$  values). As  $k$  increases, the loss drops sharply, indicating a significant improvement in image reconstruction. After a certain threshold ( $\sim 400$  eigenfaces), the loss reduction slows down, meaning additional eigenfaces contribute minimally to reconstruction quality.

### 1.2 Compression Analysis

Compression is highest when using fewer eigenfaces, as the dimensionality is significantly reduced. At  $k = 1000$ , the compression percentage reaches its lowest point, meaning almost all original image details are retained.

### 1.3 Methodology and Findings

In our dataset of all images, we selected 692 eigenfaces to balance cost efficiency while preserving video quality. This choice resulted in a reconstruction error of approximately 30 to 35, achieving around 80% compression.

## 2 Women's Dataset

[Task 2 Video]

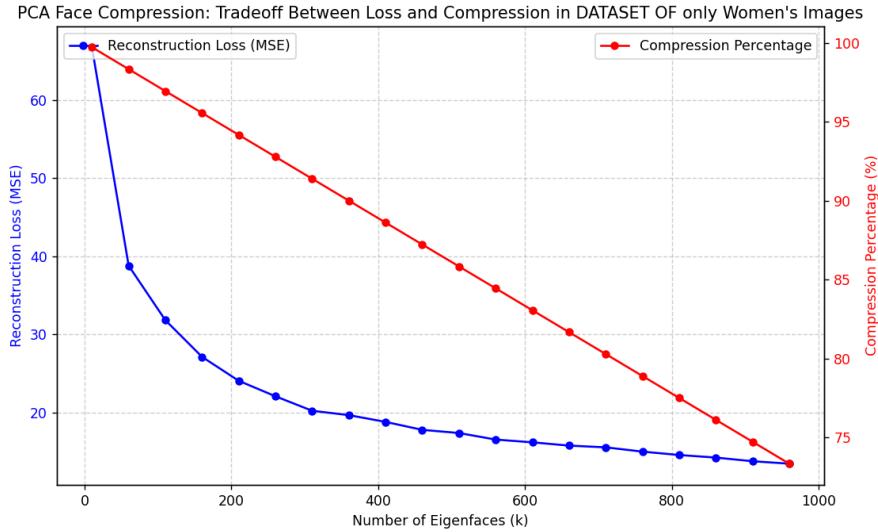


Figure 2: Eigenfaces Visualization

Table 2: Face Position as columns

|             | Straight | Left | Right  | Half Face Covered |
|-------------|----------|------|--------|-------------------|
| Cost        | 37       | 38   | 45     | 43                |
| Compression |          |      | 97.78% |                   |

### 2.1 Reconstruction Loss

The Mean Squared Error (MSE) starts high at lower  $k$  values and decreases as more eigenfaces are retained. However, the rate of improvement significantly slows down beyond  $k \approx 300$ , indicating diminishing returns in quality enhancement.

### 2.2 Compression Dynamics

The compression percentage decreases steadily as  $k$  increases, reflecting the inherent trade-off where retaining more components leads to reduced data compression.

### 2.3 Methodology and Findings

After experimenting with various  $K$  values, we settled on 431 eigenfaces for the women's dataset. This selection produced accurate facial reconstructions on both sides, though the video quality was slightly lower compared to the full-image dataset. However, with approximately 97% compression, this choice offered a balance between low computational cost and maintaining the clarity of the receiver's face.

## 3 Random 500 Images Dataset

[Task 3 Video]

### 3.1 Reconstruction Error Analysis

Key observations include:

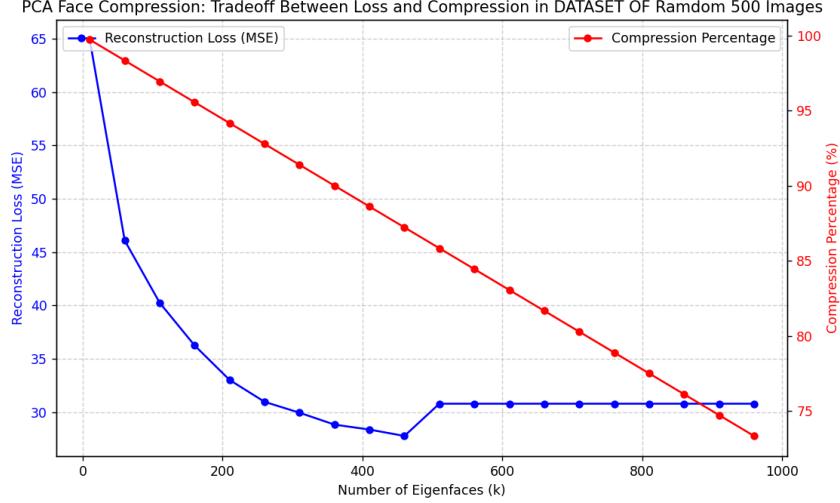


Figure 3: Eigenfaces Visualization

Table 3: Face Position as columns

|             | Straight | Left | Right | Half Face Covered |
|-------------|----------|------|-------|-------------------|
| Cost        | 35       | 34   | 45    | 48                |
| Compression |          |      |       | 90%               |

- Reconstruction Error (MSE) initially declines steeply as  $k$  increases, showing significant improvement in image quality up to  $k \approx 350$ .
- Beyond this point, the curve flattens, indicating that adding more eigenfaces results in minimal enhancement.
- Using a limited number of images resulted in a lower-dimensional subspace, leading to higher compression but a slight increase in reconstruction cost.

### 3.2 Compression Dynamics

The compression ratio follows an approximately linear decline, with higher  $k$  values leading to increased storage requirements and lower compression.

### 3.3 Methodology and Findings

For a randomly selected subset of 500 images from the dataset, we trained on a significantly smaller dataset, which naturally impacted video quality. Based on our findings, we determined 271 eigenfaces as the optimal choice. With this selection, we maintained a cost between 35 and 80 (depending on facial movements) while achieving approximately 90% compression.

## 4 Personal and Friend's Images Dataset

[Task 4 Same friend Video]

[Task 4 Different friend Video]

Table 4: Same Friend : Face Position as columns

|             | Straight | Left | Right | Half Face Covered |
|-------------|----------|------|-------|-------------------|
| Cost        | 150      | 185  | 163   | 218               |
| Compression |          |      |       | 80%               |

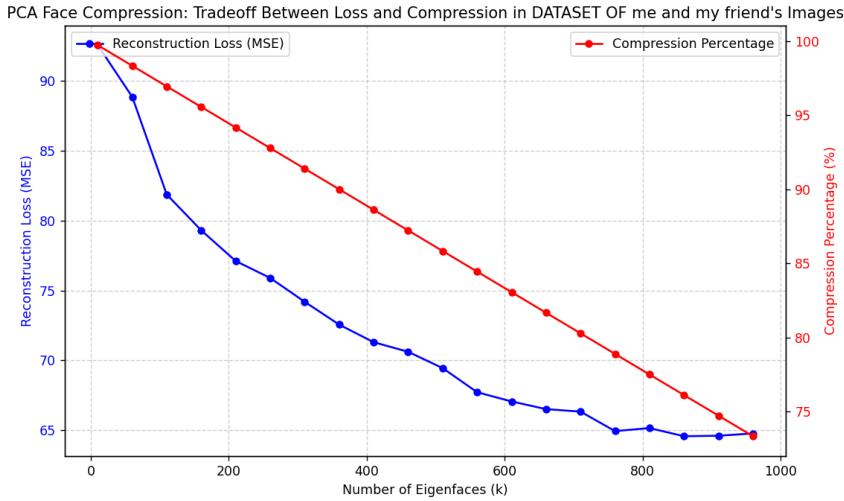


Figure 4: Eigenfaces Visualization

Table 5: Different Friend : Face Position as columns

|             | Straight | Left                              | Right  | Half Face Covered |
|-------------|----------|-----------------------------------|--------|-------------------|
| Cost        | 190      | 450 (Lighting issue on left side) | 192    | 178               |
| Compression |          |                                   | 80.78% |                   |

#### 4.1 Reconstruction Error

The reconstruction error (MSE) initially drops rapidly as the number of eigenfaces increases, indicating a significant improvement in image quality up to  $k \approx 300$ .

- Beyond this point, the rate of decline in MSE becomes more gradual, suggesting diminishing returns in reconstruction fidelity.
- The compression ratio follows a steady downward trend, emphasizing the inherent tradeoff: higher accuracy requires more storage.
- The high reconstruction cost indicated that eigenfaces failed to generalize well to untrained individuals.

#### 4.2 Methodology and Findings

In this analysis, we collected 1,000 images each from ourselves and a friend. Since these images were self-captured, their quality, combined with the limited training dataset of 2,000 images, led to a higher reconstruction cost and significantly impacted video quality.

Initially, faces appeared only in a recognizable form. However, after experimenting with different eigenface values, we found that using 670 eigenfaces provided a decently recognizable face. Although facial movements in the video caused significant variations in cost and the compression rate was lower, the overall video quality remained at a reasonable level.

### 5 Failure Cases

- Smaller dataset size led to higher compression but reduced the model's ability to capture key facial variations.
- Training on one person's images made it difficult to reconstruct another person's face accurately.
- Significant reconstruction variations occurred due to facial movements, affecting dynamic expressions.