

A Comprehensive Report on PCA

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1 ALL IMAGES DATASET

[Task 1 Video]

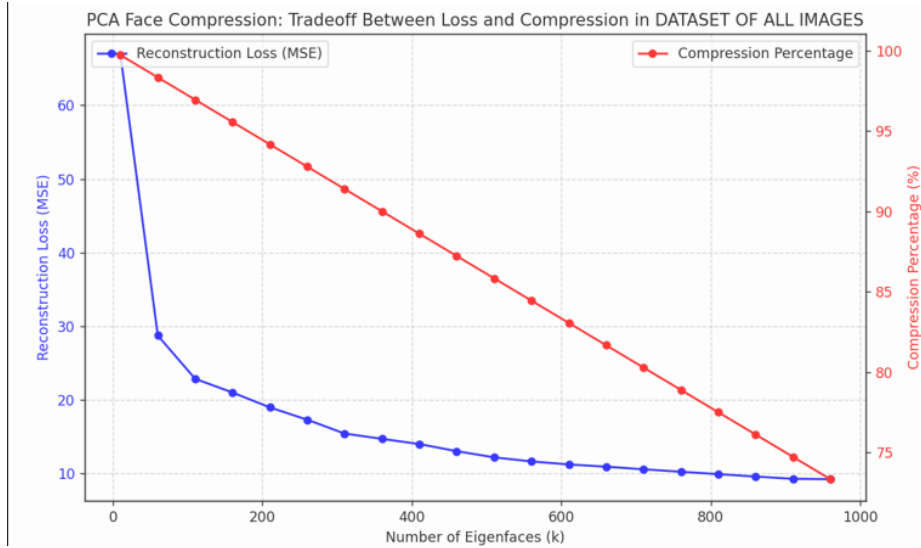


Figure 1: Eigenfaces Visualization

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 (~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]

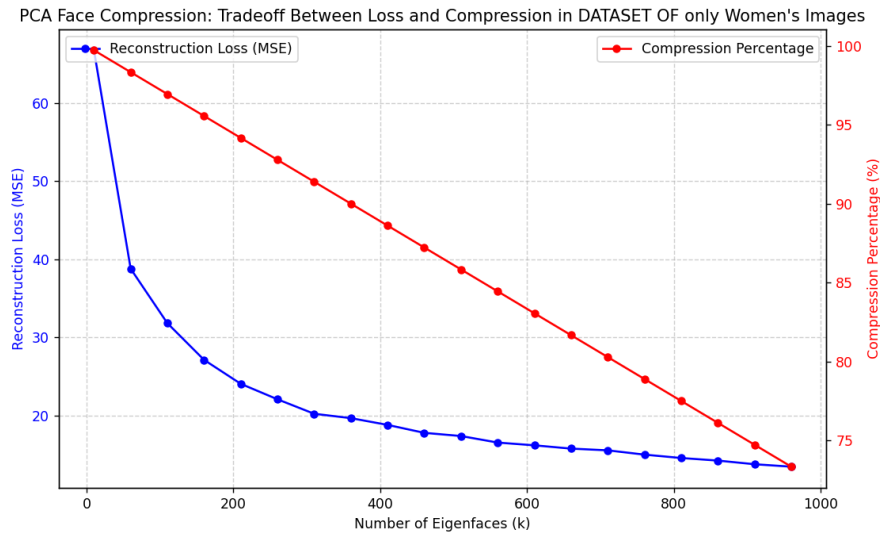


Figure 2: Eigenfaces Visualization

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:

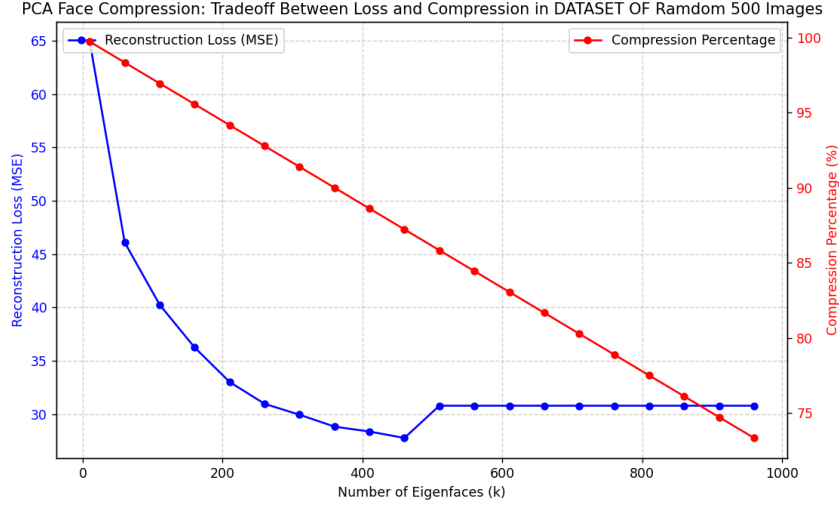


Figure 3: Eigenfaces Visualization

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%			

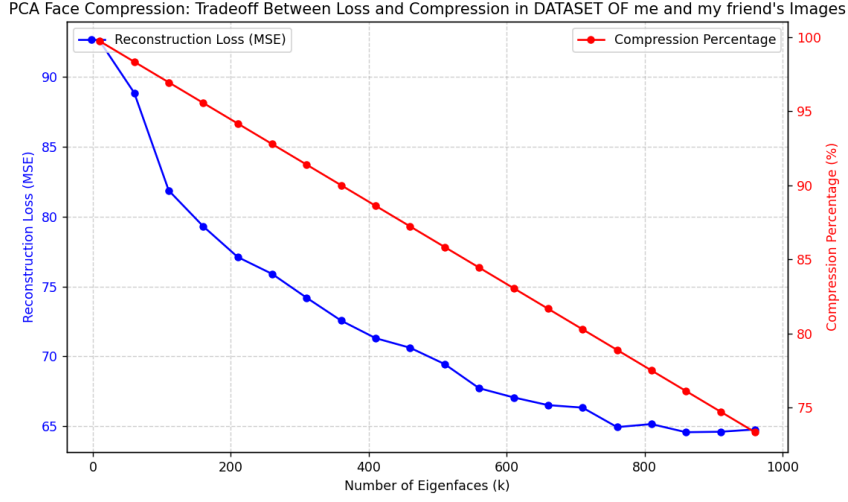


Figure 4: Eigenfaces Visualization

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.