

2 Low-Rank Approximation

Low-rank approximation tries to find an approximation to a given matrix, where the approximation matrix has a lower rank compared to the original matrix. This is useful for mathematical modeling and data compression. Mathematically, given a matrix M , we try to find \hat{M} in the following optimization problem,

$$\underset{\hat{M}}{\operatorname{argmin}} \|M - \hat{M}\|_F \quad \text{subject to} \quad \operatorname{rank}(\hat{M}) \leq k \quad (1)$$

where $\|A\|_F = \sqrt{\sum_i \sum_j a_{ij}^2}$ is the Frobenius norm, i.e., the sum of squares of all entries in the matrix, followed by a square root.

This problem can be solved using Singular Value Decomposition (SVD). Specifically, let $M = U\Sigma V^T$, where $\Sigma = \operatorname{diag}(\sigma_1, \dots, \sigma_n)$. Then a rank- k approximation of M can be written as $\hat{M} = U\hat{\Sigma}V^T$, where $\hat{\Sigma} = \operatorname{diag}(\sigma_1, \dots, \sigma_k, 0, \dots, 0)$. In this problem, we aim to perform this approximation method on gray-scale images, which can be thought of as a 2D matrix.

- (a) Using the image `low-rank_data/face.jpg`, perform a rank-5, rank-20, and rank-100 approximation on the image. Show both the original image as well as the low-rank images you obtain in your report.
- (b) Now perform the same rank-5, rank-20, and rank-100 approximation on `low-rank_data/sky.jpg`. Show both the original image as well as the low-rank images you obtain in your report.
- (c) In one plot, plot the Mean Squared Error (MSE) between the rank- k approximation and the original image for both `low-rank_data/face.jpg` and `low-rank_data/sky.jpg`, for k ranging from 1 to 100. Be sure to label each curve in the plot. The MSE between two images $I, J \in \mathbb{R}^{m \times n}$ is

$$\operatorname{MSE}(I, J) = \sum_{i,j} (I_{i,j} - J_{i,j})^2. \quad (2)$$

Low Rank Approximation Low Rank Approximation

Arturo Cuomo



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Low Rank Approximation Low Rank Approximation Book Review: Unveiling the Power of Words

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Table of Contents Low Rank Approximation Low Rank Approximation

1. Understanding the eBook Low Rank Approximation Low Rank Approximation
 - The Rise of Digital Reading Low Rank Approximation Low Rank Approximation
 - Advantages of eBooks Over Traditional Books
2. Identifying Low Rank Approximation Low Rank Approximation
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Low Rank Approximation Low Rank Approximation
 - User-Friendly Interface
4. Exploring eBook Recommendations from Low Rank Approximation Low Rank Approximation
 - Personalized Recommendations
 - Low Rank Approximation Low Rank Approximation User Reviews and Ratings

- Low Rank Approximation Low Rank Approximation and Bestseller Lists
- 5. Accessing Low Rank Approximation Low Rank Approximation Free and Paid eBooks
 - Low Rank Approximation Low Rank Approximation Public Domain eBooks
 - Low Rank Approximation Low Rank Approximation eBook Subscription Services
 - Low Rank Approximation Low Rank Approximation Budget-Friendly Options
- 6. Navigating Low Rank Approximation Low Rank Approximation eBook Formats
 - ePub, PDF, MOBI, and More
 - Low Rank Approximation Low Rank Approximation Compatibility with Devices
 - Low Rank Approximation Low Rank Approximation Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Low Rank Approximation Low Rank Approximation
 - Highlighting and Note-Taking Low Rank Approximation Low Rank Approximation
 - Interactive Elements Low Rank Approximation Low Rank Approximation
- 8. Staying Engaged with Low Rank Approximation Low Rank Approximation
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Low Rank Approximation Low Rank Approximation
- 9. Balancing eBooks and Physical Books Low Rank Approximation Low Rank Approximation
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Low Rank Approximation Low Rank Approximation
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Low Rank Approximation Low Rank Approximation
 - Setting Reading Goals Low Rank Approximation Low Rank Approximation
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Low Rank Approximation Low Rank Approximation
 - Fact-Checking eBook Content of Low Rank Approximation Low Rank Approximation
 - Distinguishing Credible Sources

13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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