Authored by
1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Project 2

Project Description

The overall project is a Content-Based Image Retrieval (CBIR) system implemented in C++. It consists of several tasks aimed at developing a robust image matching algorithm using different feature extraction techniques and distance metrics. The tasks include:

1. Single Histogram Matching: Compute and compare RGB histograms using sum-of-squared-difference as the distance metric.
2. Histogram Matching: Implement histogram matching with a normalized color histogram using histogram intersection as the distance metric.
3. Multi-Histogram Matching: Extend histogram matching to use multiple histograms representing different spatial parts of the image, combined using weighted averaging.
4. Feature Vector Matching: Use pre-computed feature vectors from a CSV file and compare them using cosine distance as the distance metric.
5. CBIR System Integration: Combine the feature vectors obtained from the CSV file with histogram matching using chi-squared distance as the distance metric.

The project leverages OpenCV for image processing tasks, Boost libraries for file system operations, and implements custom distance metrics and feature extraction techniques. The final system includes a live demonstration of image retrieval using the on-device camera feed, continuously displaying the closest matching image from a database directory.

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Task 1: Baseline Matching:

Required Images:

Required image: 1

```
Top 3 matches:
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.1016.jpg (Distance: 0)
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0986.jpg (Distance: 17255)
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0641.jpg (Distance: 23262)
```

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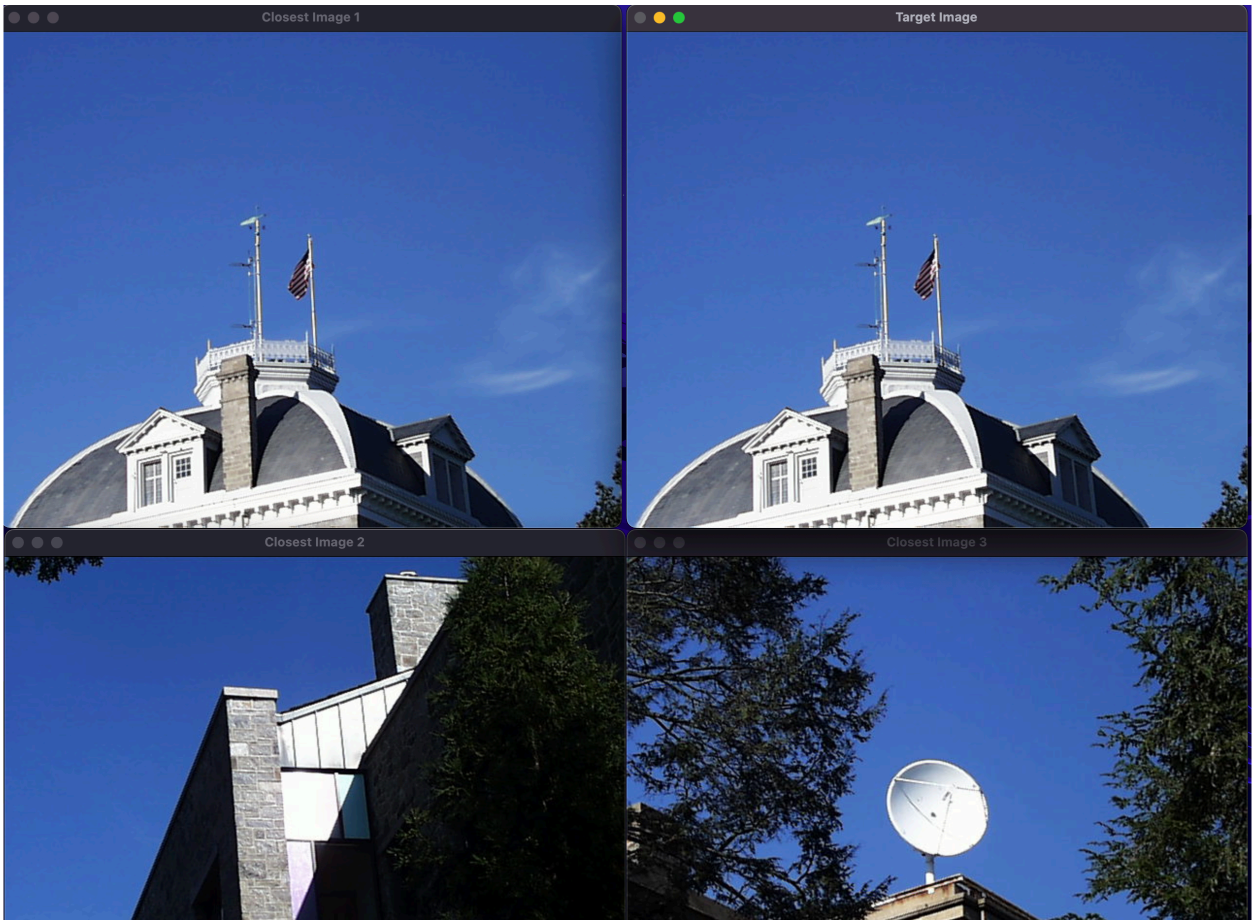
Task 2: Histogram Matching:

Required images:



Required image: 2

```
Top 3 matches:
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0164.jpg (Distance: 0)
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.1032.jpg (Distance: 3.22251)
/Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0110.jpg (Distance: 4.08139)
```

Task 3: Multi-histogram Matching:

Required images:

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Required image: 3

```
Distance: 0, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0274.jpg
Distance: 1.107, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0412.jpg
Distance: 1.12678, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0409.jpg
Distance: 1.25634, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0886.jpg
```

Task 4: Texture and Color:

Required images:

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1. Aadhi Aadhavan Balasubramanian - 002785595
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Required image: 4

```
Distance: 0, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0535.jpg
Distance: 0.0752127, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0332.jpg
Distance: 0.0792821, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0734.jpg
Distance: 0.0810592, Image: /Users/aadhi/Desktop/CS5330/Project2/olympus/pic.0141.jpg
```

Task 6: Compare DNN Embeddings and Classic Features

Target 1: 1072

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Required image DNN Embeddings: **Images 5-7**:

Classical Features: **Images 8-11**

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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Target Image 2: pic.0948

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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Required images DNN embeddings Images 12-14:

Classical Features images 15-18:

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1. Aadhi Aadhavan Balasubramanian - 002785595
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While Deep Neural Network (DNN) embedding vectors offer profound advantages in capturing complex, high-dimensional features of images, asserting that they are always better is an oversimplification. Their superiority largely depends on the context and requirements of the specific image retrieval task. For instance, in applications where nuanced semantic understanding and generalization across diverse image types are critical, DNN embeddings excel by leveraging the depth of features learned from vast datasets. An example is the retrieval of images based on abstract themes, such as "happiness" or "solitude," where DNNs can effectively grasp and match the conceptual underpinnings across varied visual representations.
However, for more straightforward tasks, such as matching based on simple shapes or colors, traditional feature extraction methods might not only suffice but also offer advantages in terms of computational efficiency and simplicity.

Task 5: Deep Network Embeddings:

Target: pic.0893.jpg

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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Required images: images 19-22




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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Required image:

```
Distance: -3.46985e-08, Image: pic.0893.jpg
Distance: 0.151768, Image: pic.0897.jpg
Distance: 0.176157, Image: pic.0136.jpg
Distance: 0.224857, Image: pic.0146.jpg
```

Target: pic.0164.jpg

Required Matching images: 23 -26

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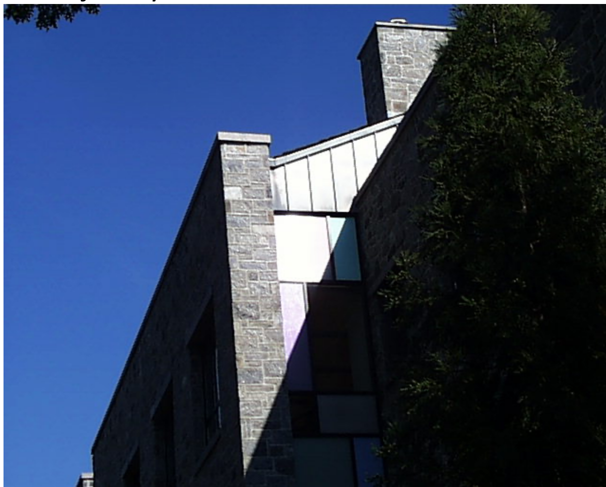
1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497



```
Distance: -3.14548e-08, Image: pic.0164.jpg
Distance: 0.212189, Image: pic.1032.jpg
Distance: 0.212836, Image: pic.0213.jpg
Distance: 0.235137, Image: pic.0690.jpg
```

Task7: Custom Design:

Authored by
1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Required Images:

Target 1: pic.1015.jpg

Result:

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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497




```
Distance: 2.093e-08, Image: pic.1015.jpg
Distance: 0.722269, Image: pic.0385.jpg
Distance: 0.724462, Image: pic.0129.jpg
Distance: 0.736368, Image: pic.0959.jpg
```

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1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Target 2: 1067

Required images:

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2. Harishraj Udaya Bhaskar - 002760497

```
Distance: 1.97395e-08, Image: pic.1067.jpg
Distance: 0.951046, Image: pic.0850.jpg
Distance: 1.15967, Image: pic.0780.jpg
Distance: 1.26846, Image: pic.0012.jpg
```

Extension:

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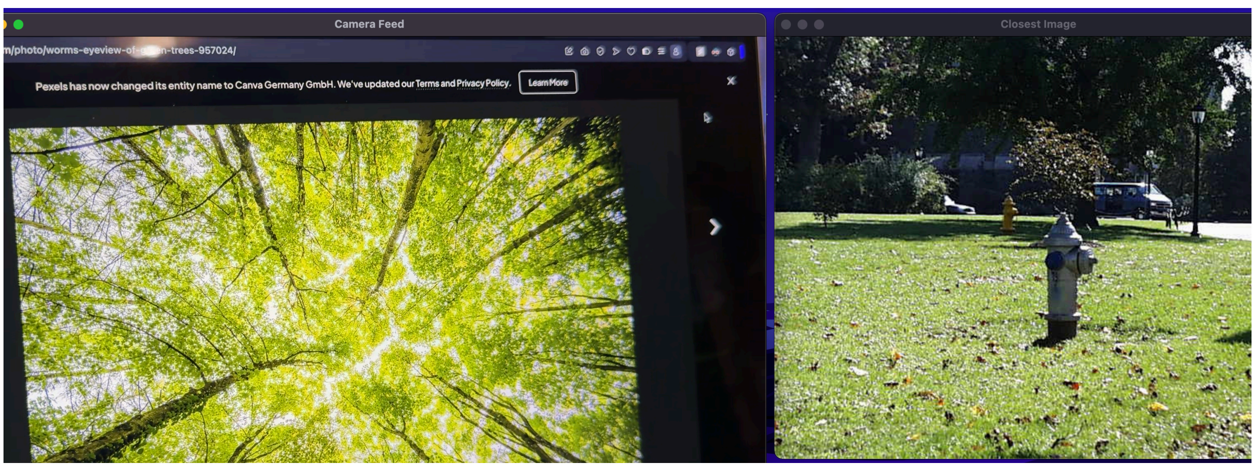
1. Aadhi Aadhavan Balasubramanian - 002785595
2. Harishraj Udaya Bhaskar - 002760497

Live image matching:

The extension to the Content-Based Image Retrieval (CBIR) system involves integrating real-time image analysis with existing image matching techniques. By continuously capturing video from the device camera, the system provides users with instant feedback on their surroundings. Utilizing multi-histogram matching with Chi-squared distance, the system identifies and displays the image from a directory that most closely resembles the live video feed, enhancing user interaction and engagement. This extension enhances the practicality of the CBIR system by allowing users to seamlessly explore similar images in their environment, opening up new possibilities for interactive image search applications. The real-time nature of the extension offers immediate feedback and enriches the user experience by providing a dynamic and interactive interface.



A short reflection of what you learned.

Authored by
1. Aadhi Aadhavan Balasubramanian - 002785595
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Reflecting on the project, I gained valuable insights into the intricacies and challenges of developing Content-Based Image Retrieval (CBIR) systems. One of the key learnings was the importance of feature selection in the effectiveness of image retrieval. Simple features like pixel intensities or basic color histograms can offer a starting point, but they often fall short when dealing with complex visual content that requires more sophisticated descriptors, such as texture patterns or deep learning embeddings.

Another significant lesson was understanding the trade-offs between different similarity measurement techniques. For example, while sum-of-squared differences is straightforward to implement, it may not capture the perceptual similarity between images as effectively as histogram intersection or cosine similarity in high-dimensional feature spaces. This highlighted the need to carefully choose the distance metric that aligns with the nature of the features being compared.

The exploration of deep learning embeddings particularly stood out, revealing the power of pre-trained neural networks in extracting rich, high-level features from images. This approach demonstrated a marked improvement in retrieval accuracy, showcasing the potential of leveraging machine learning for CBIR tasks. However, it also introduced considerations around computational cost and the necessity of having a large and diverse dataset for training.

Acknowledgements

- **https://stackoverflow.com/questions/795972/chi-squared-probability-function-in-c**
- **https://towardsdatascience.com/histogram-matching-ee3a67b4cbc1**
- **https://ieeexplore.ieee.org/document/6738468**
- **https://stackoverflow.com/questions/52053827/training-a-neural-network-in-python-and-deploying-in-c**
- **https://stackoverflow.com/questions/20013804/how-to-compare-an-image-with-database-in-c-opencv**
- **https://docs.opencv.org/4.x/d1/dfb/intro.html**

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