CS 5330

Pattern Recognition and Computer Vision

Project 2: Context Based Image Retrieval

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Overview of the overall project:

The primary objective of this project is to understand the pattern and color matching at the pixel level in photos. To perform image comparison, we employed a range of feature vectors that include direct pixel values, 2D and 3D RGB histograms that consider spatial information, the combination of color and texture, and specific patterns for images. We examined several distance metrics such as sum square distance, L1 distance, histogram intersection, thresholding etc., to determine the dissimilarities between two photos based on the histogram. By calculating the difference between the histograms generated from the feature vectors, we can determine the images that are most like our target input. The project consists of two programs that make up its overall structure.

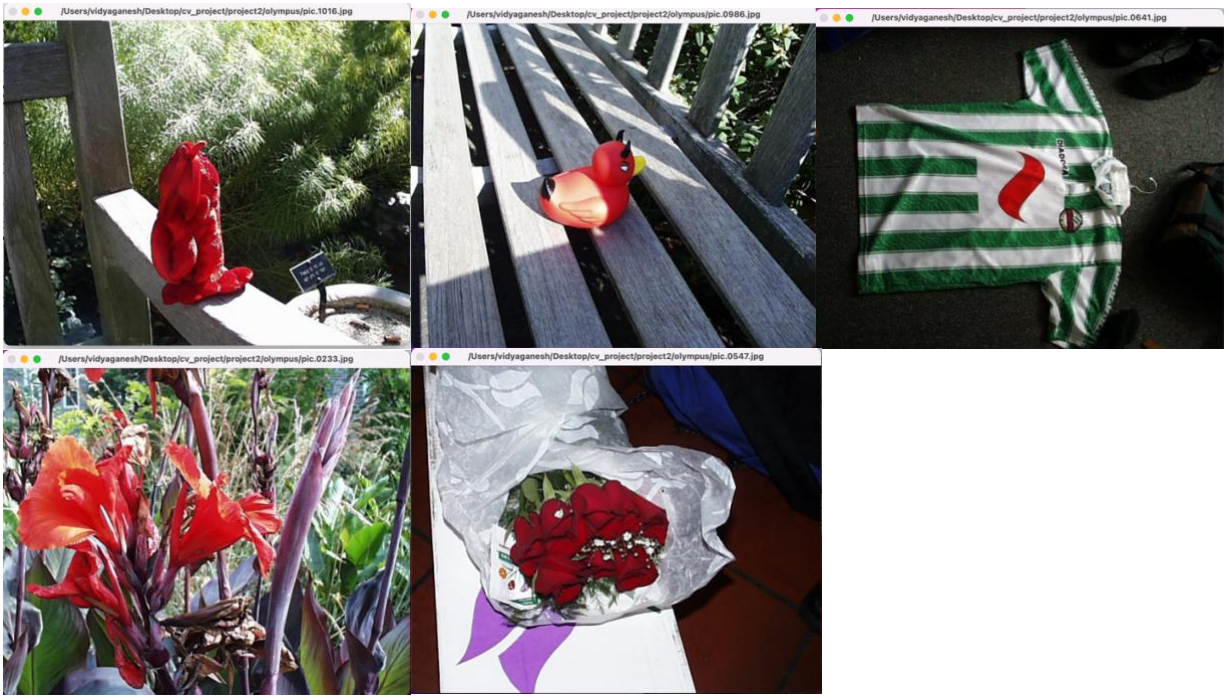
The project has two programs:

- The first one reads all the images, computes the feature vectors and saves it in different csv files for each feature type to use on different tasks.
- Based on a given feature type the second program compares the target feature vector with all the feature vectors present in the respective csv file that was created in the previous step and shows the top n results.

As part of **extensions**:

1. We have implemented GUI to run all the tasks in this project making it more sophisticated than command line.
2. We also tried identifying bananas and blue bins as part of our second extensiond.
3. As another extension we also tried additional **features and matching** methods

Required Image 1: *Show the top three matches for the target image pic.1016.jpg. My top three matches* ***are pic.0986.jpg, pic.0641.jpg,*** *and* ***pic.0233.jpg****.*



Terminal Output:

```
(base) vidyaganesh@Vidyas-MacBook-Air bin % ./main
pixels: 81
Reading /Users/vidyaganesh/Desktop/cv_project/project2/feature_db.csv
Finished reading CSV file
File: 0 ,MSE:  0,  Path:  /Users/vidyaganesh/Desktop/cv_project/project2/olympus/pic.1016.jpg
File: 1 ,MSE:  28731,  Path:  /Users/vidyaganesh/Desktop/cv_project/project2/olympus/pic.0986.jpg
File: 2 ,MSE:  41959,  Path:  /Users/vidyaganesh/Desktop/cv_project/project2/olympus/pic.0641.jpg
File: 3 ,MSE:  86092,  Path:  /Users/vidyaganesh/Desktop/cv_project/project2/olympus/pic.0233.jpg
File: 4 ,MSE:  107059,  Path:  /Users/vidyaganesh/Desktop/cv_project/project2/olympus/pic.0547.jpg
(base) vidyaganesh@Vidyas-MacBook-Air bin %
```

Fig Set 1: From the terminal output it can be observed that comparing the image with itself results in a distance of 0 (in this case comparing **pic.1016.jpg** with itself). The other images that were listed in the top 5 with ascending order of their MSEs are **pic.0986.jpg**, **pic.0641.jpg**, **pic.0233.jpg**, and **pic.0547.jpg.**

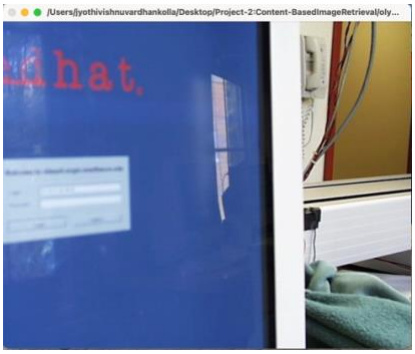
We utilized baseline matching for task 1, comparing the 9x9 pixels in the center of the photo. Sum square difference is used as a measure of distance. The matched output from the terminal is displayed above for the target image pic.1016.jpg.

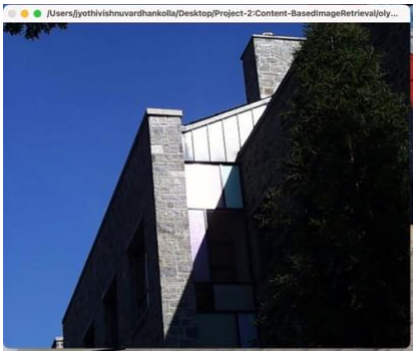
MSE: 0; File Name: **pic.1016.jpg**
MSE: 28731; File Name: **pic.1016.jpg**
MSE: 41959; File Name: **pic.1016.jpg**
MSE: 86092; File Name: **pic.1016.jpg**

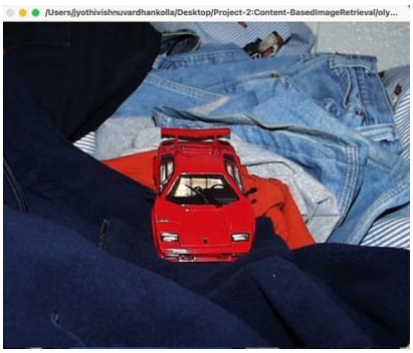
Required image 2: *Histogram Matching: show the top three matches for the target image pic.0164.jpg.*

Target Image: ***pic.0164****.jpg*

(a) Below results for query **pic.0164** were obtained with a whole image **rg** chromaticity histogram using **16 bins** for each of **r** and **g** and histogram intersection as the distance metric.







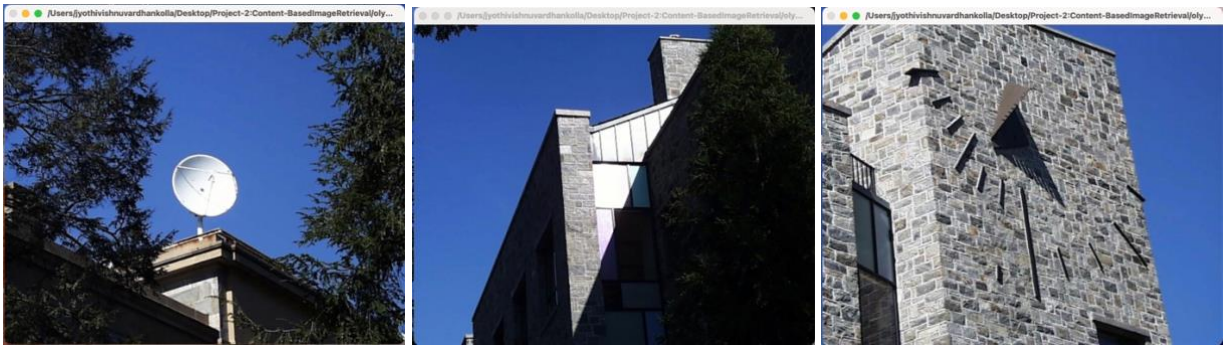
Top 3 Matches: Image 1: ***pic.0080****.jpg; Image 2:* ***pic.1032****.jpg; Image 3:* ***pic.0461****.jpg*

```
Finished reading CSV file
Matching hist2d1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0164.jpg:0.00391275
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0080.jpg:0.310187
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.1032.jpg:0.375979
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0461.jpg:0.442229

Process finished with exit code 0
```

Fig Set 2 (a): From the terminal output and the images above, it can be observed that the top three matches for the image pic.0164.jpg are **pic.0080.jpg**, **pic.1032.jpg**, and **pic.0461.jpg.**

(b) Below results for query pic.0164 were obtained with a whole image RGB histogram using **8 bins** for each of RGB and histogram intersection as the distance metric.



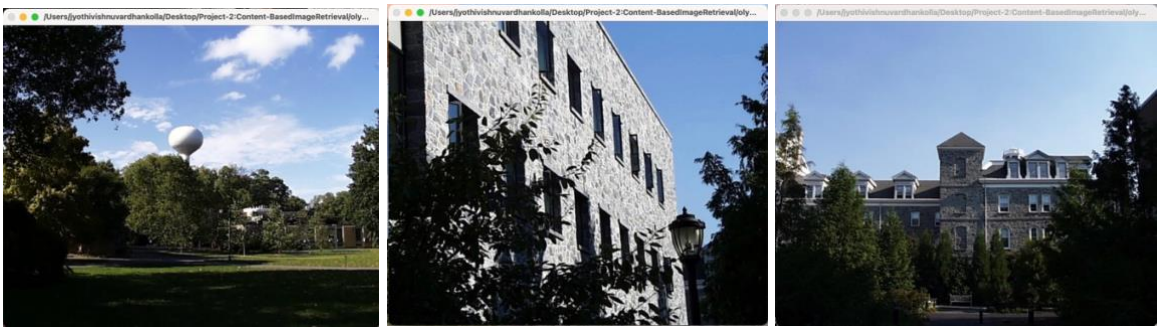
*Top 3 Matches: Image 1: **pic.0110**.jpg; Image 2: **pic.1032**.jpg; Image 3: **pic.0092**.jpg*

```
Matching hist3d1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0164.jpg:0.000990093
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0110.jpg:0.57558
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.1032.jpg:0.576317
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0092.jpg:0.610934
```

Fig Set 2 (b): From the terminal output and the images above, it can be observed that the top three matches for the image pic.0164.jpg are **pic.0110.jpg**, **pic.1032.jpg**, and **pic.0092.jpg.**

Required Image 3: *Multi Histogram:* *show the top three matches for the target image pic.0274.jpg.*

*Target Image: **pic.0274**.jpg*



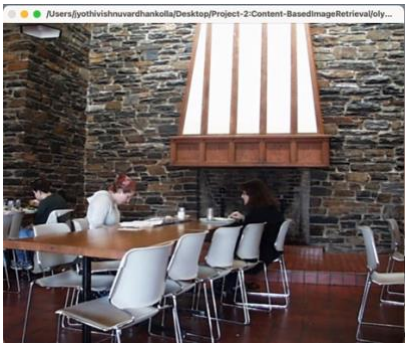
*Top 3 Matches: Image 1: **pic.0273**.jpg; Image 2: **pic.1031**.jpg; Image 3: **pic.0213**.jpg.*
These results for query pic.0274 were obtained with two RGB histograms, representing the top and bottom halves of the image, using **8 bins** for each of RGB and histogram intersection as the distance metric.

```
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/multiHistFeaturevec
Finished reading CSV file
Matching top bottom hist1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0274.jpg:1.00258
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0273.jpg:1.35513
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.1031.jpg:1.38819
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0213.jpg:1.40987
```

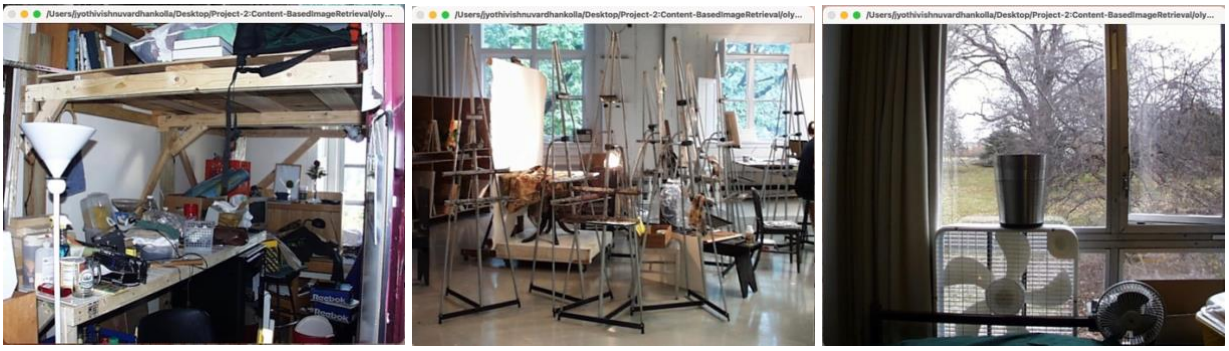
Fig Set 3: From the terminal output and the images above, it can be observed that the top three matches are pic.0273.jpg, pic.1031.jpg, pic.0213.jpg.

Here we used a 3D RGB histogram with **eight bins** as the feature vector. Each image is split into a top and a bottom section, with each portion having its own RGB histogram that is subsequently saved in the feature vector. Histogram intersection is used as a measure of distance.

Required Image 4: ***Texture:*** *show the top three matches for the target image pic.0535.jpg and show how they differ when compared to tasks 2 and 3.*



Target Image: ***pic.0535****.jpg*

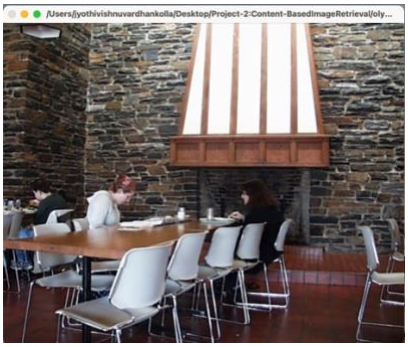


```
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/textureHistogram.csv
Finished reading CSV file
Matching textureHist1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0535.jpg:0.00271642
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0171.jpg:0.336884
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0004.jpg:0.35126
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0605.jpg:0.356078
```

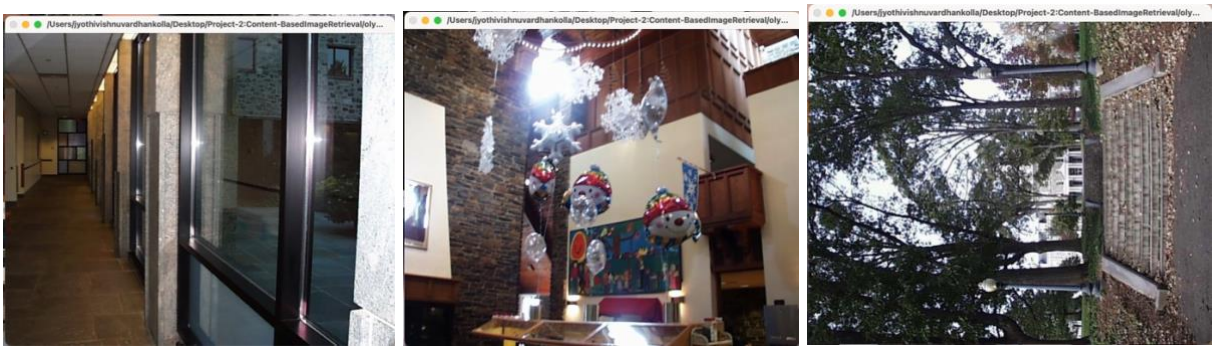
Fig Set 4: From the terminal output and the images above, it can be observed that the top three matches are pic.0171.jpg, pic.0004.jpg, pic.0605.jpg

We first used a 3D histogram on the RGB image and used a 3D histogram using the gradient magnitude on the image on top of which we used a 3D histogram and used the distance metric as the intersection of the histograms.

The difference when compared to task 2:


Target Image

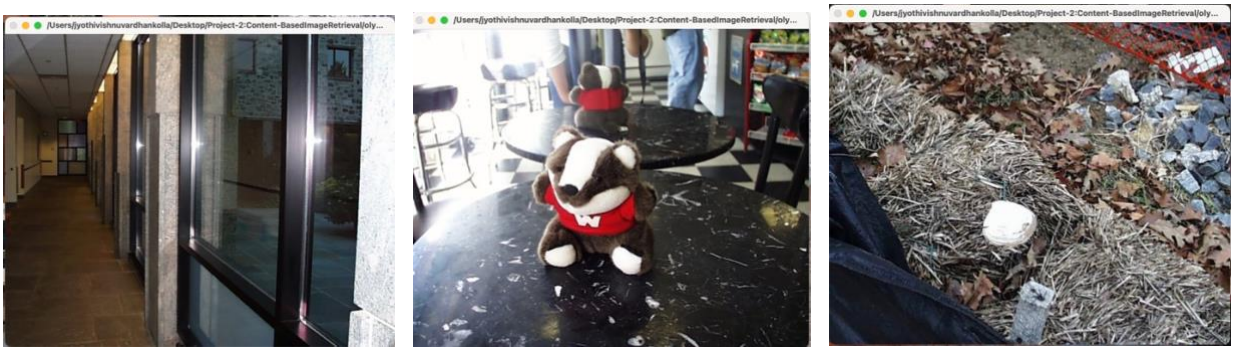
```
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/Hist3DfeatureVector.csv
Finished reading CSV file
Matching hist3d1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0535.jpg:0.00160718
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0285.jpg:0.221018
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0628.jpg:0.226091
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0952.jpg:0.262761
```



The difference when compared to task 3:

Target is the same image as the previous one

```
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/multiHistFeaturevectors.csv
Finished reading CSV file
Matching top bottom hist1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0535.jpg:1.00279
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0285.jpg:1.30242
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.1105.jpg:1.34271
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0972.jpg:1.34274
```

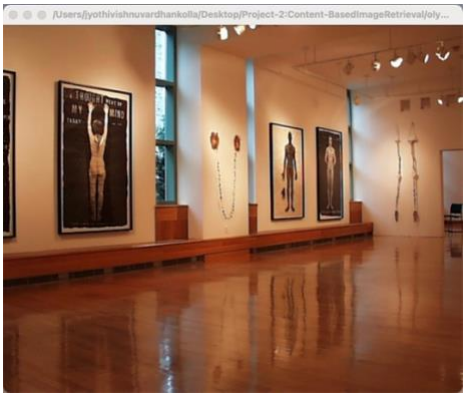


Required Image 5: *for two target images of your choice, show the top ten results. It's also helpful to show some of the least similar results. If you want to show a video of your system in action, include a link to the video in your readme file.*

```
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/multiHistLeftRight.csv
Finished reading CSV file
Matching left right1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0014.jpg:1.00371
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0017.jpg:1.15998
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0025.jpg:1.39825
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0019.jpg:1.39988
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0024.jpg:1.44067
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0013.jpg:1.45479
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0018.jpg:1.45711
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0015.jpg:1.51803
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0088.jpg:1.53691
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0183.jpg:1.538
```

Fig Set 5: The terminal output with the top 10 matches is as above in the terminal.

We chose the below image as the target image and the goal was to find all the images matching this scene in the below image. We performed them using one histogram on the right half and another on the left half and used the distance metric as intersection of histograms to find all the relevant images in the databases. We also tried taking other images that matched the scene in the below image and set them as targets to see if we obtained similar results. And we were able to retrieve images that were like the target in almost all cases.



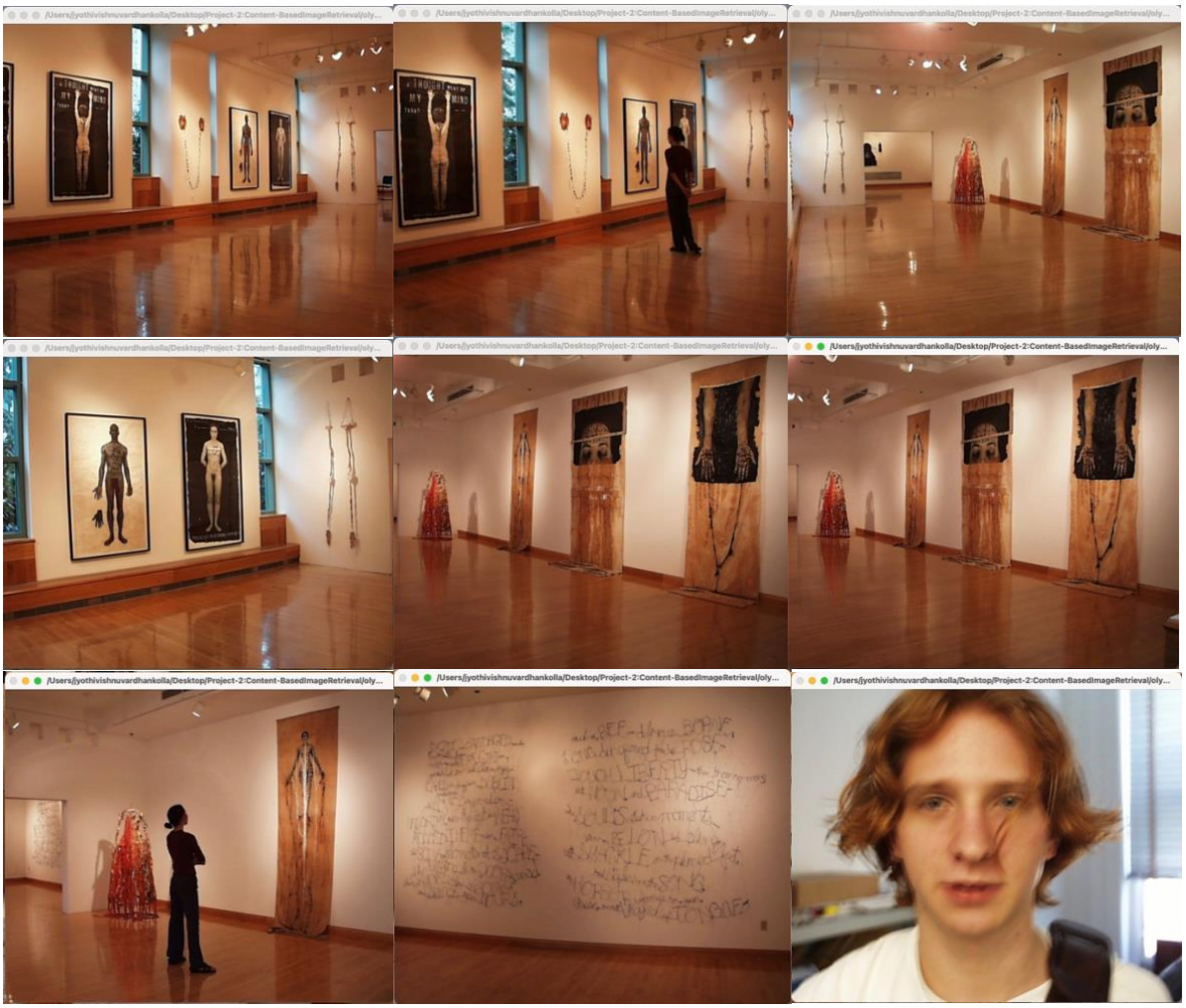


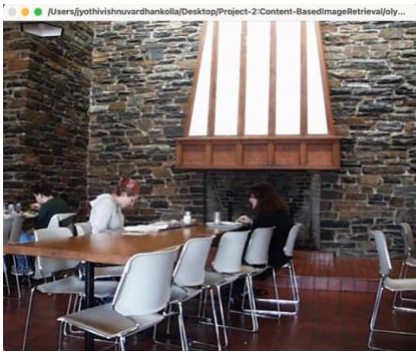
Fig Set Ext 5: *The images in row 1 is the target, the second third and fourth rows have the top 10 images that closely match the target image given above.*

Extensions

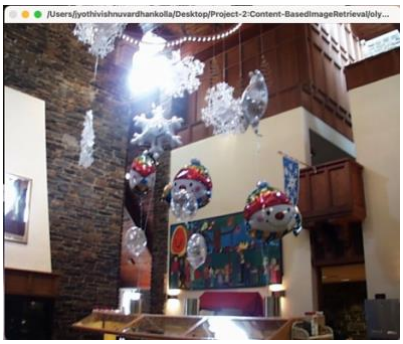
Extension 1: Create **additional features** and matching methods. Compare and contrast your different methodologies.

We first used a 3D histogram on the RGB image and used a 3D histogram using the Laplacian Filter on the image on top of which we used a 3D histogram and used the distance metric as the intersection of the histograms.

```
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/cmake-build-debug/Matching.cpp /Us
Reading /Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/content-based-image-retrieval/LaplacianHistFeatures.csv
Finished reading CSV file
Laplacian filter
1106/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0535.jpg:0.00191391
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0171.jpg:0.296619
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0628.jpg:0.326913
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0285.jpg:0.337138
/Users/jyothivishnuvardhankolla/Desktop/Project-2:Content-BasedImageRetrieval/olympus/pic.0605.jpg:0.341254
```



Target Image pic.0535.jpg



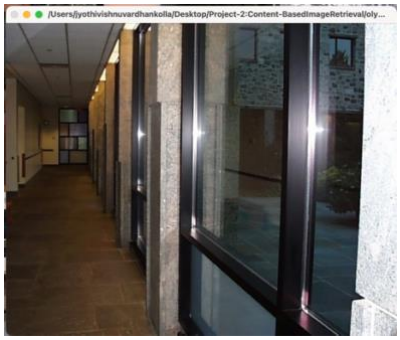


Fig Set Ext 2: *The first image in row 1 is the target, the second and the third rows have the top 4 images which are : pic.0171.jpg, pic.0628.jpg, pic.0285.jpg, pic.0605.jpg*

Extension 2: Design a GUI for your system or otherwise make it more sophisticated than a command line program

A sample of how the GUI looks and how it is used can be found in the video uploaded in drive in the following link:

https://drive.google.com/file/d/1UuEBb3m2AwyCe4LkpZjt6xZBvkaIij3f/view?usp=share_link

Fig Set Ext 2: *The first image shows an example of all the permissible operations in this project via the GUI.*

Extension 3: See if you can find as many pictures with bananas as possible given an input image containing banana.

We designed a customized matching function after cropping the image to 150x150 to make sure it captures the center of each image. We converted the image to HSV space and applied thresholding based on color. In this case yellow.

In the image below we can find some the yellow matches with the target of a banana image. Though it doesn't identify all the bananas in the top five we observed that all the bananas where part of the top 20 when we set N as 20.

 Target Image

Other images that were part of the top 20 include:

Fig Set Ext 3: The first few images captured are as follows

Additional Points:

1. We also tried using entropy metric and obtained the following results. We retrieved the images that have high disorderness as follows:

Reflections:

Through this assignment, we have gained knowledge on how to match the images using the color histogram, multi histograms, and thresholding techniques. We also discovered how important it is to take texture into account in images. We also built a GUI to run tasks 1 to 5 and the extensions. The GUI provides the user an interface to choose which operation they want to perform of the all the given tasks. It also makes is more sophisticated rather than using the command line.

Acknowledgements:

Professor Bruce, TA Ravina and TA Santhosh helped us with the clarifications in task 4 and 5 which was about texture matching and multi-histograms. They also gave us some suggestions to implement the extensions to identify bananas in the image dataset.