1. **Implementation**
   1. Computing Features
      * The program is fed a folder name containing subfolders for each class. The images within each subfolder are appended to the list for that class.
      * Each image is opened and resized using PIL.
      * Each image is converted to a numpy array and concatenated using reshape(-1).
   2. Training
      * Each class-list of images is randomly divided into 5 equal folds.
        + The fifth fold is used for testing, the fourth fold is used as the hold-out for training.
      * Optimal parameters were found by evaluating SVMs with different costs and gamma.
        + A grid search was used to test different cost-gamma pairs.
        + The first three folds were used to model the SVMs.
        + The fourth folds were used to evaluate the SVMs.
      * A one-vs-all SVM is modeled using for each class using the first three folds of each class and the optimal parameters for that class.
   3. Testing
      * The overall classifier was evaluated using all of the class SVMs.
      * The fifth folds were used as the test set.
      * Probabilities for each class for each image were found using the class SVMs.
      * The argmax class of the probabilities was assigned to each image.
2. **Descriptions**

**Parameter Evaluations:**

Soccer\_ball Classifier

Linear SVM

|  |  |
| --- | --- |
| **Cost** | **Accuracy** |
| **1E-12** | 82.0 |
| **1E-09** | 82.0 |
| **1E-06** | 85.2 |
| **1E-03** | 85.2 |
| **1** | 85.2 |
| **1E+03** | 85.2 |
| **1E+06** | 85.2 |
| **1E+09** | 85.2 |
| **1E+12** | 85.2 |

RBF SVM

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gamma** | | | | |
| **Cost** | **3.26E-13** | **3.26E-10** | **3.26E-07** | **0.000326** | **0.325521** |
| **1.00E-09** | 81.97 | 81.97 | 81.97 | *91.80* | *91.80* |
| **1.00E-06** | 81.97 | 81.97 | 81.97 | *91.80* | *91.80* |
| **0.001** | 81.97 | 81.97 | 88.52 | *91.80* | *91.80* |
| **1** | 81.97 | 81.97 | *91.80* | *91.80* | *91.80* |

Dollar\_bill Classifier

Linear SVM

|  |  |
| --- | --- |
| **Cost** | **Accuracy** |
| **1E-12** | 83.6 |
| **1E-09** | 83.6 |
| **1E-06** | 88.5 |
| **1E-03** | 90.2 |
| **1** | 90.2 |
| **1E+03** | 90.2 |
| **1E+06** | 90.2 |
| **1E+09** | 90.2 |
| **1E+12** | 90.2 |

RBF SVM

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gamma** | | | | |
| **Cost** | **3.26E-13** | **3.26E-10** | **3.26E-07** | **0.000326** | **0.325521** |
| **1.00E-09** | 83.61 | 83.61 | 83.61 | *90.16* | *90.16* |
| **1.00E-06** | 83.61 | 83.61 | 83.61 | *90.16* | *90.16* |
| **0.001** | 83.61 | 83.61 | 88.52 | *90.16* | *90.16* |
| **1** | 83.61 | 83.61 | *90.16* | *90.16* | *90.16* |

Dalmatian Classifier

Linear SVM

|  |  |
| --- | --- |
| **Cost** | **Accuracy** |
| **1E-12** | 78.7 |
| **1E-09** | 78.7 |
| **1E-06** | 85.2 |
| **1E-03** | 85.2 |
| **1** | 85.2 |
| **1E+03** | 85.2 |
| **1E+06** | 85.2 |
| **1E+09** | 85.2 |
| **1E+12** | 85.2 |

RBF SVM

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gamma** | | | | |
| **Cost** | **3.26E-13** | **3.26E-10** | **3.26E-07** | **0.000326** | **0.325521** |
| **1.00E-09** | 78.69 | 78.69 | 78.69 | *83.61* | *83.61* |
| **1.00E-06** | 78.69 | 78.69 | 78.69 | *83.61* | *83.61* |
| **0.001** | 78.69 | 78.69 | 80.33 | *83.61* | *83.61* |
| **1** | 78.69 | 78.69 | *83.61* | *83.61* | *83.61* |

Sunflower Classifier

Linear SVM

|  |  |
| --- | --- |
| **Cost** | **Accuracy** |
| **1E-12** | 72.1 |
| **1E-09** | 72.1 |
| **1E-06** | 95.1 |
| **1E-03** | 95.1 |
| **1** | 95.1 |
| **1E+03** | 95.1 |
| **1E+06** | 95.1 |
| **1E+09** | 95.1 |
| **1E+12** | 95.1 |

RBF SVM

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gamma** | | | | |
| **Cost** | **3.26E-13** | **3.26E-10** | **3.26E-07** | **0.000326** | **0.325521** |
| **1.00E-09** | 72.13 | 72.13 | 72.13 | 90.16 | 90.16 |
| **1.00E-06** | 72.13 | 72.13 | 72.13 | 90.16 | 90.16 |
| **0.001** | 72.13 | 72.13 | *93.44* | 90.16 | 90.16 |
| **1** | 72.13 | 72.13 | 90.16 | 90.16 | 90.16 |

Pizza Classifier

Linear SVM

|  |  |
| --- | --- |
| **Cost** | **Accuracy** |
| **1E-12** | 83.6 |
| **1E-09** | 83.6 |
| **1E-06** | 90.2 |
| **1E-03** | 90.2 |
| **1** | 90.2 |
| **1E+03** | 90.2 |
| **1E+06** | 90.2 |
| **1E+09** | 90.2 |
| **1E+12** | 90.2 |

RBF SVM

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Gamma** | | | | |
| **Cost** | **3.26E-13** | **3.26E-10** | **3.26E-07** | **0.000326** | **0.325521** |
| **1.00E-09** | 83.61 | 83.61 | 83.61 | 83.61 | 83.61 |
| **1.00E-06** | 83.61 | 83.61 | 83.61 | 83.61 | 83.61 |
| **0.001** | 83.61 | 83.61 | *85.25* | 83.61 | 83.61 |
| **1** | 83.61 | 83.61 | 83.61 | 83.61 | 83.61 |

**Classification Accuracies:**

Linear SVMs:

|  |  |
| --- | --- |
| **Class** | **Accuracy** |
| Overall | 73% |
| soccer\_ball | 80% |
| dollar\_bill | 70% |
| dalmatian | 54% |
| sunflower | 94% |
| pizza | 60% |

Confusion Martrix:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | soccer\_ball | dollar\_bill | dalmatian | sunflower | pizza |
| soccer\_ball | **8** | 0 | 2 | 0 | 0 |
| dollar\_bill | 0 | **7** | 2 | 0 | 1 |
| dalmatian | 4 | 0 | **7** | 1 | 1 |
| sunflower | 1 | 0 | 0 | **16** | 0 |
| pizza | 0 | 0 | 2 | 2 | **6** |

RBF SVMs:

|  |  |
| --- | --- |
| **Class** | **Accuracy** |
| Overall | 83% |
| soccer\_ball | 80% |
| dollar\_bill | 80% |
| dalmatian | 54% |
| sunflower | 100% |
| pizza | 100% |

Confusion Matrix:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | soccer\_ball | dollar\_bill | dalmatian | sunflower | pizza |
| soccer\_ball | **8** | 0 | 2 | 0 | 0 |
| dollar\_bill | 0 | **8** | 1 | 0 | 1 |
| dalmatian | 3 | 1 | **7** | 1 | 1 |
| sunflower | 0 | 0 | 0 | **17** | 0 |
| pizza | 0 | 0 | 0 | 0 | **10** |

**Some Successful Classifications:**

Both linear and RBF classifiers worked excellently on sunflower images, and the RBF classifier also identified pizza images extremely well. This is probably due to the unique colorations of sunflowers and pizzas in this dataset. Sunflowers are the only predominantly yellow images, and pizzas have more red than the other classes. Our “tiny image” representation is able to capture the pixel colors well.

Sunflower/image\_0012.jpg



Pizza/image\_0002.jpg



**Some Failed Classifications:**

Both linear and RBF classifiers struggled with Dalmatian images, and they were frequently miss-classified as soccer balls. This error was expected, because both Dalmatians and soccer balls are black and white spotted, and several images in both classes feature grass around the object. Our “tiny image” representation does not capture shape well, which is the primary difference between Dalmatian and soccer ball images.

Dalmatian/image\_0023.jpg



**Improvements to Classification:**

SVMs are extremely powerful classifiers, but they rely on informative representations of the objects to be classified. Therefore this classification would best be improved by improving on the “tiny image” representation. Better features include a combination of color histograms, texton histograms, and edge direction histograms. In addition, simply using more images would build SVMs with more generalizability.