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** |