```
setDir = fullfile('./cutlery');
imds = imageDatastore(setDir, 'IncludeSubfolders', true, 'LabelSource',
'foldernames');

% Bag of features
bag = bagOfFeatures(imds, 'VocabularySize', 500, 'PointSelection',
'Detector', 'Verbose', false);

% Classifier training
classifier = trainImageCategoryClassifier(imds, bag);
```

```
Training an image category classifier for 5 categories.
--------------------------------------------------------
* Category 1: bread_knife
* Category 2: fork
* Category 3: ladle
* Category 4: spatula
* Category 5: spoon

* Encoding features for 223 images...done.

* Finished training the category classifier. Use evaluate to test the classifier on a test set.
```

```


% Split the dataset into 80% for training and 20% for testingnImds,
testImds] = splitEachLabel(imds, 0.8, 'randomized');
[trainImds, testImds] = splitEachLabel(imds, 0.8, 'randomized');

% Evaluate the classifier on the test image datastore
confMatrix = evaluate(classifier, testImds);
```

```
Evaluating image category classifier for 5 categories.
-------------------------------------------------------

* Category 1: bread_knife
* Category 2: fork
* Category 3: ladle
* Category 4: spatula
* Category 5: spoon

* Evaluating 46 images...done.

* Finished evaluating all the test sets.

* The confusion matrix for this test set is:


                                PREDICTED
KNOWN          | bread_knife   fork   ladle   spatula   spoon
---------------------------------------------------------------
bread_knife    | 1.00          0.00   0.00    0.00      0.00
fork           | 0.08          0.83   0.00    0.00      0.08
ladle          | 0.09          0.00   0.82    0.00      0.09
spatula        | 0.00          0.00   0.00    1.00      0.00
spoon          | 0.00          0.00   0.00    0.00      1.00

* Average Accuracy is 0.93.
```

```

```

```
% Display class-specific accuracy in a more readable table format
fprintf('\nClass Specific Accuracy:\n');
```

```
Class Specific Accuracy:
```

```
classAccTable = array2table(classSpecificAccuracy, 'RowNames',
classifier.Labels);
disp(classAccTable);
```

| | classSpecificAccuracy |
|---|---|
| **bread_knife** | 1 |
| **fork** | 0.83333 |
| **ladle** | 0.81818 |
| **spatula** | 1 |
| **spoon** | 1 |

```


% Class-specific accuracy from the confusion matrix
classSpecificAccuracy = diag(confMatrix) ./ sum(confMatrix, 2);

% Precision, Recall, and F1 score for each class
numClasses = size(confMatrix, 1);
precision = zeros(numClasses, 1);
recall = zeros(numClasses, 1);
f1Score = zeros(numClasses, 1);

for i = 1:numClasses
    TP = confMatrix(i, i);
    FP = sum(confMatrix(:, i)) - TP;
    FN = sum(confMatrix(i, :)) - TP;

    precision(i) = TP / (TP + FP);
    recall(i) = TP / (TP + FN);
    f1Score(i) = 2 * (precision(i) * recall(i)) / (precision(i) + recall(i));
end

% Display class-specific metrics in a table
metricsTable = table(precision, recall, f1Score, 'RowNames',
classifier.Labels);
fprintf('Class-Specific Metrics:\n');
```

```
Class-Specific Metrics:
```

```
disp(metricsTable);
```

| | precision | recall | f1Score |
|---|---|---|---|
| **bread_knife** | 0.85161 | 1 | 0.91986 |
| **fork** | 1 | 0.83333 | 0.90909 |
| **ladle** | 1 | 0.81818 | 0.9 |

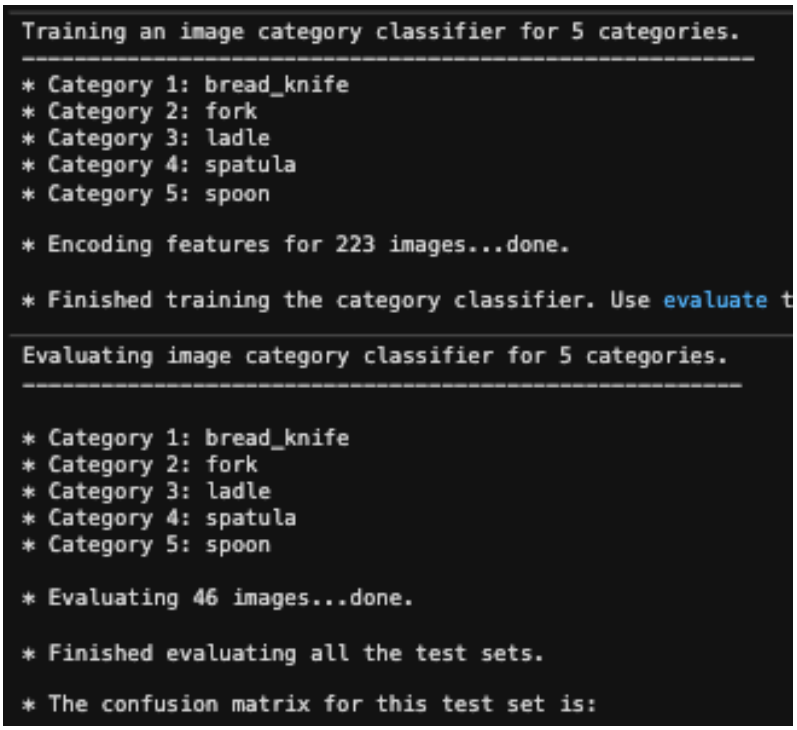
| | | | |
|---|---|---|---|
| **spatula** | 1 | 1 | 1 |
| **spoon** | 0.85161 | 1 | 0.91986 |

```
% Overall accuracy
fprintf('\n');
overallAccuracy = sum(diag(confMatrix)) / sum(confMatrix(:));
fprintf('Overall accuracy: %.2f%%\n', overallAccuracy * 100);
```

```
Overall accuracy: 93.03%
```

## Question 6

This question required using a machine learning classifier designed to identify five types of household cutlery: bread knives, forks, ladles, spatulas, and spoons. Utilizing a bag of features approach, the classifier was evaluated for its accuracy, precision, recall, and F1 scores across these categories. The output from running the classifier is shown in the image below:



```
* The confusion matrix for this test set is:

                              PREDICTED
KNOWN          | bread_knife   fork   ladle   spatula   spoon
-------------------------------------------------------------
bread_knife    | 1.00          0.00   0.00    0.00      0.00
fork           | 0.08          0.83   0.00    0.00      0.08
ladle          | 0.09          0.00   0.82    0.00      0.09
spatula        | 0.00          0.00   0.00    1.00      0.00
spoon          | 0.00          0.00   0.00    0.00      1.00

* Average Accuracy is 0.93.
Class Specific Accuracy:
                  classSpecificAccuracy
                  _____________________

    bread_knife                   1
    fork                    0.83333
    ladle                   0.81818
    spatula                       1
    spoon                         1



Class-Specific Metrics:
                  precision    recall     f1Score
                  _________    ______     _______

    bread_knife     0.85161         1     0.91986
    fork                  1   0.83333     0.90909
    ladle                 1   0.81818         0.9
    spatula               1         1           1
    spoon           0.85161         1     0.91986
Overall accuracy: 93.03%
```

**Key Results and Performance Metrics**

- **Overall Accuracy:** The classifier achieved an overall accuracy of 93.03%, indicating a high level of proficiency in correctly classifying the cutlery images.
- **Class-Specific Accuracy:**
  - Bread Knife and Spatula: Perfect accuracy (100%).
  - Fork and Ladle: Lower accuracy (83.33% and 81.82%, respectively), suggesting some challenges in these categories.
- **Precision and Recall:**
  - High precision (1.00) for forks, ladles, and spatulas indicates that when the classifier predicts these classes, it is highly reliable.
  - The recall is lower for forks (83.33%) and ladles (81.82%), showing some instances were missed or misclassified, primarily as other cutlery types.
- **F1 Score:** Reflects a balance between precision and recall, with scores ranging from 0.9 to 1.00, highlighting effective classification with room for improvement in forks and ladles.

**Confusion Matrix Analysis**

The confusion matrix provided deeper insights:

- **Perfect Classification:** Bread knives, spatulas, and spoons were classified without errors.
- **Misclassifications:** Forks and ladles showed minor confusions, particularly with each other and with spoons, indicating potential visual similarities that could be addressed.

**Implications**

- The classifier demonstrates robust capabilities for distinguishing clearly distinct items like bread knives, spatulas, and spoons.
- The slight difficulties in classifying forks and ladles suggest a need for refinement in feature extraction or additional training data to capture subtle distinctions better.
- The high precision across most categories ensures that the model's predictions are reliable, which is crucial for applications where misclassification could have significant consequences.