Item Recyclability Identification Based on Image Classification

Xiaoyi Chen

Overview & Recap

The goal of my project is to identify the recyclability of an item by taking a picture of it. Training set contains hundreds of images, and is processed by computer vision methods. To simplify the problem, a few restrictions are enforced on the quality of images: Images should be taken in a clear white blank background to ensure the item does not confuse with irrelevant objects; Item must be entirely contained within the image.
The algorithm learns the major image feature extracted and classify the new images taken by users.

Progress

Up to this point, I have collected a few hundred of images of recyclable and non-recyclable items.

Recyclable items include several material categories:
Aluminum: Aluminum Foil.
Cans: Pie tins, Tin Cans, Steel cans.
Glass: Glass bottles, glass jars.
Paper: Office paper, newspaper, paper rolls, paper cups, tissue box.
Plastic: #1 - #7 including soda bottles, detergent bottles, spray bottles, tupperware.

Non-recyclable items include the following:
Trash bags, Candy Wrap, Bubble Wrap, Potato chip bags, Light bulbs, Soiled material.

I observed that to accurately define the recyclability of a given item by visual features, human's approach is to identify the kind and material of the item. However, the visual patterns of materials vary a lot in different items and it is difficult to identify the global category of the item by local-scale features. For example, a recyclable item like white paper and non-recyclable item like trash bag can have similar local visual appearance, which is hard to tell apart even by human beings given the resolution of the camera. Therefore, it is unlikely to precisely identify the kind of material by simply applying local-feature filters. A feasible solution is to imitate the way humans recognize a item. The algorithm places great importance on contours. It doesn't have to

recognize the exact specific object in the training database, since many kinds of recyclable materials contain a wide variety of items (like various brands of plastic package and wraps).

I have investigated several Computer Vision methods to effectively extract the item of interest from background.
In the beginning I tried to use Corner detection (as in figure 1). Due to lost of features and presence of irrelevant points, I decided to adopt edge detection.

figure 1

Here is the preprocessing procedure of images (illustrated in figure 2): First Gaussian smoothing

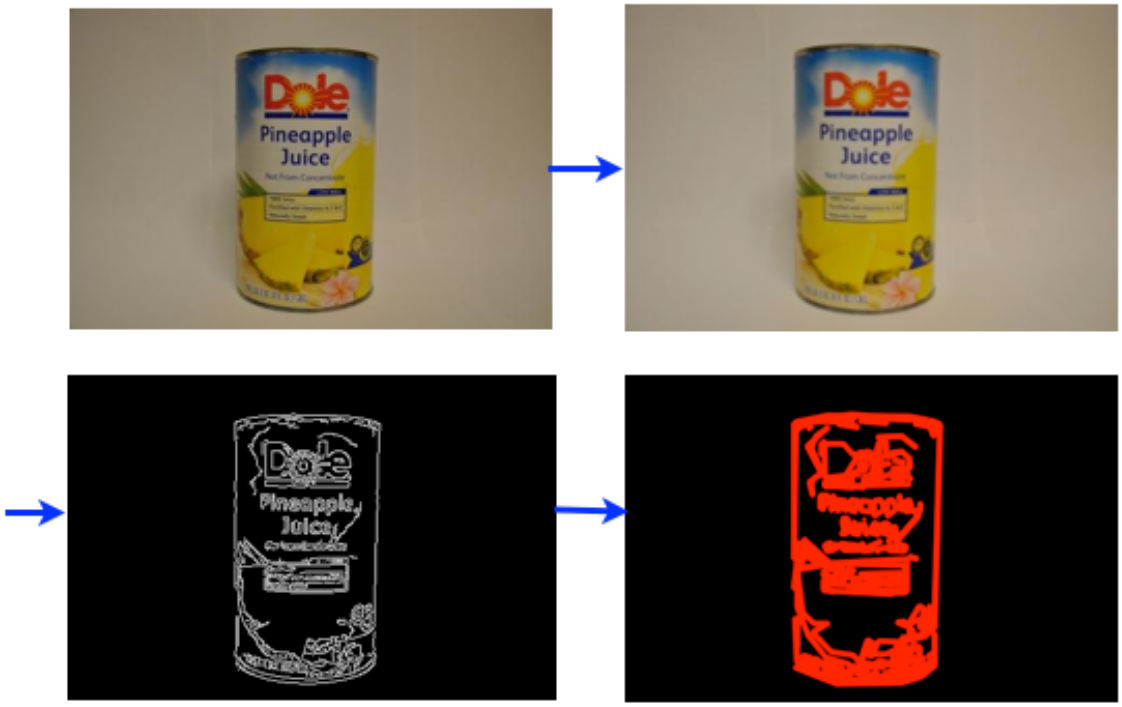

figure 2

is performed to eliminate noises of input image. Then I run a Canny edge detector to detect the edges (steep gradient in color) in the input image. Lastly I run a contour extraction procedure to

find the connected components of edges. This extraction routine has mostly been performing pretty well.
I performed dimensionality reduction methods on contours and conduct classification experiments (features of test images are preprocessed in the same way as training images).

Results

Dimensionality reduction need to be performed on contours to eliminate redundant information. The set of images I used contains 92 training images (44 positive examples and 48 negative examples) and a small set of 17 test images.

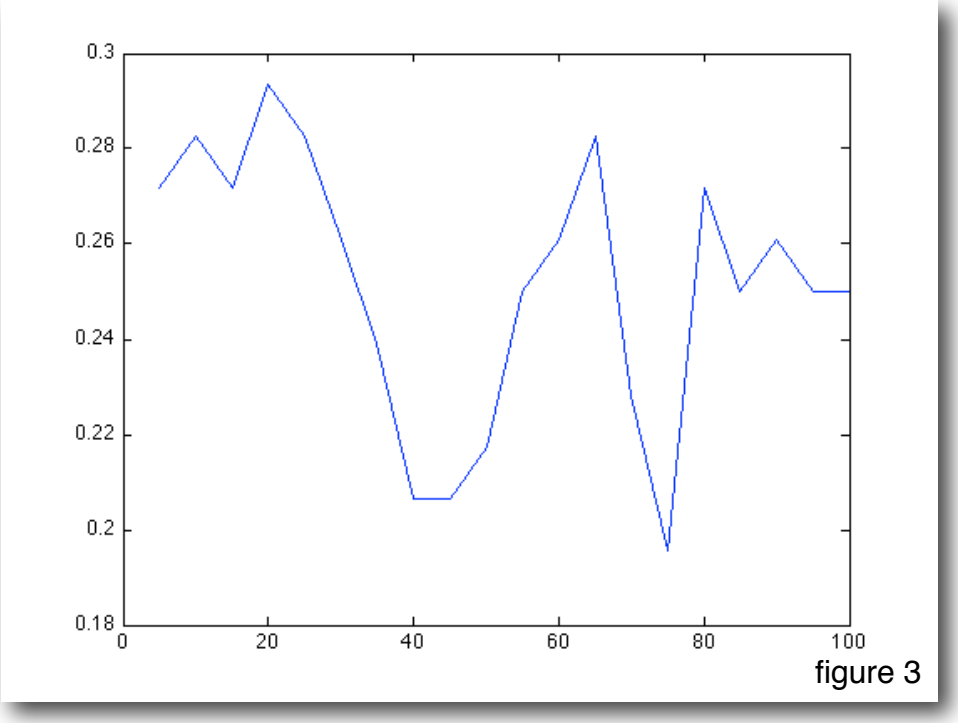

figure 3

Initially I tried PCA(Principal Component Analysis), k-Nearest Neighbor algorithm for classification. Figure 3 shows how error rate changes with increased dimensionality on training set. We can see that at dimension = 75 the error rate reached a relatively small point. Nevertheless, the classifier obtained by PCA is not performing well on the small test set I am using (42% error rate), making me turn to LDA (Linear Discriminant Analysis).

The objective of Linear Discriminant Analysis is to perform dimensionality reduction while preserving as much of the class discriminatory information as possible. Since there are two classes in total, the dimension is reduced to 1 by LDA. Figure 4 illustrates a good separation of training data. The classification based on LDA achieved a reasonable result (24% error rate).

Since I have only a pretty limited number of test images, the preliminary result I have gotten so far might not be a very good indicator of the actual performance of the algorithm. But after

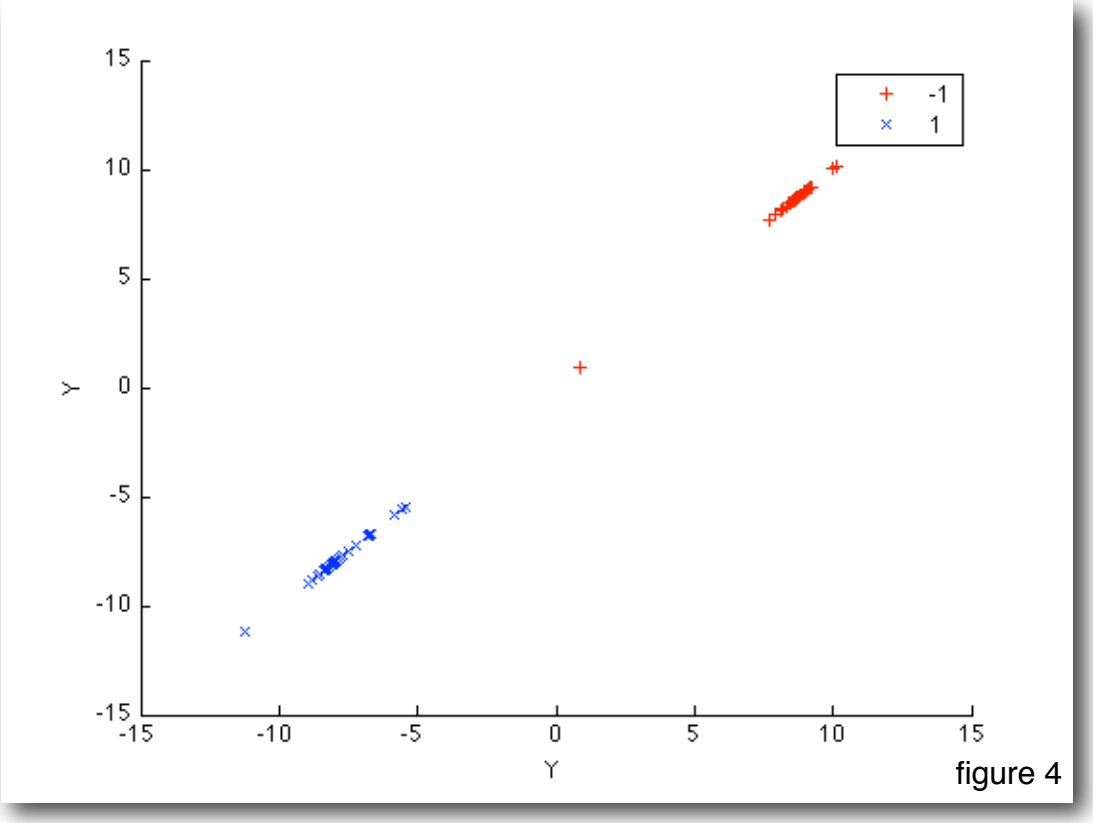

figure 4

analyzing the result, I found a few limitations to the method. Items such as toothpastes and bottles have a much distinguishable appearance from other objects, but hardly if any differences exist between items like recyclable paper cup and non-recyclable styrofoam cup. Besides, recyclable regulations are not the same across the country, much less the world. To be more informative to the users, the system should decide the detailed category of the item, and whether it should be put in a recyclable bin, a compostable bin or a non-recyclable bin (trash bin).Although the training image set contains a number of categories, it still only covers a small number of all possible kinds of items. More precise categorization of the item image might be necessary for practical use.

Things to do

Things have been kept within schedule but there's still work to do to polish the project. According to the schedule, I plan to improve the classification algorithm by May 20. I will find how I can incorporate texture and appearance features for recognition and probably would add more subclasses in addition to the existing two classes. My option for an alternative classification algorithm is Decision Trees algorithm (Random Forests) and carry out experiments. Regarding the data set, I will take more pictures for training and testing, and take pictures of similar item to enhance the robustness of the algorithm. Time permitting, I will try to improve the performance of item extraction using local histogram.