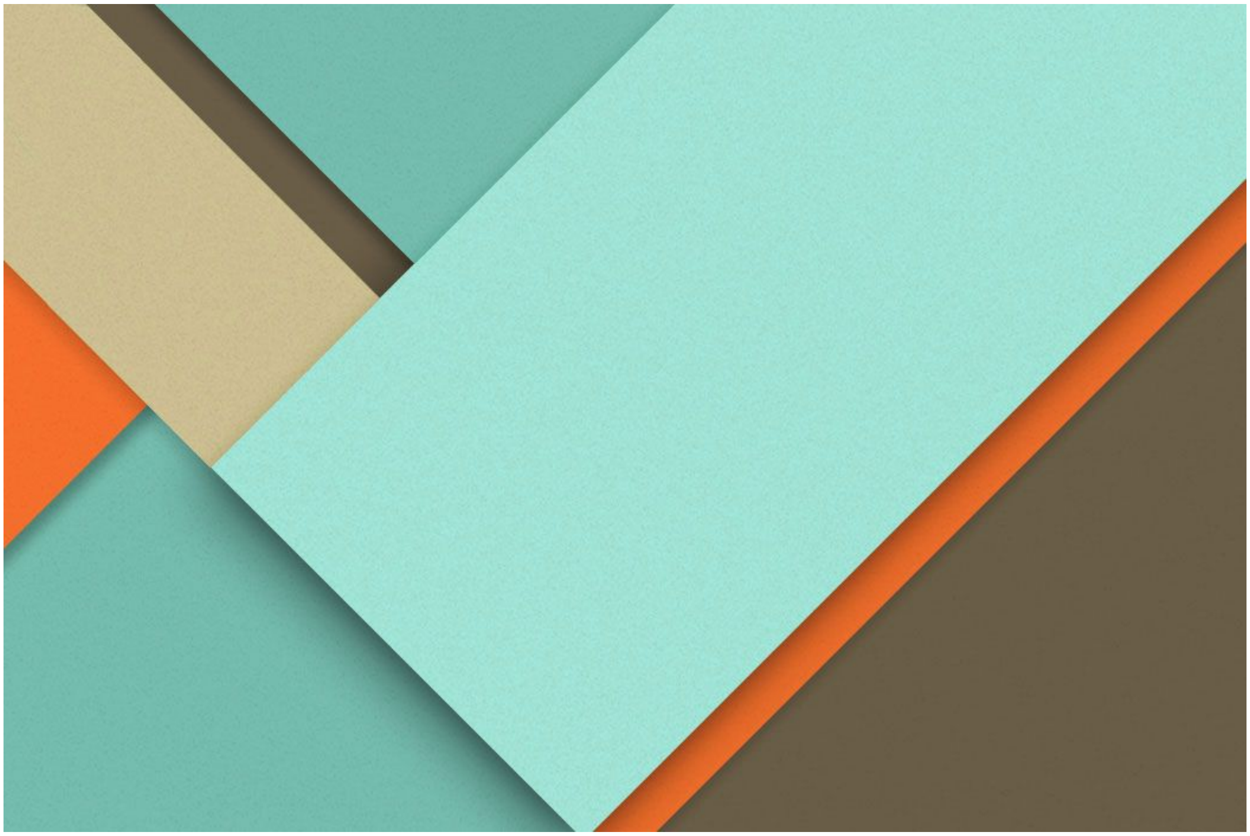

On-Tree Apple Recognition Using Texture Properties and Color Data

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Overview

This document aims to provide a surface-level understanding of the methodology and science behind image-processing systems designed for object recognition - in this case, in-orchard fruit recognition.

Before discussing the use of stereo vision to accurately distinguish fruits in orchards, it is necessary t cover the basics of algorithms that locate fruits in a single image. Recognition is based on both color (especially redness of apples) and texture-based edge detection (area thresholding followed by circle fitting). In cluttered environments, Laplacian filters have been found to be helpful (they further clutter the environment in order to differentiate between fruits and foliage).

1. The ultimate aim is to use a pair of stereo cameras as part of the set up shown in so that the manipulating machine can pick the apples.
2. The manipulator is mounted on a pair of telescopic linear stages so that the robot can reach areas that are outside the width of the tractort.
3. By lifting and lowering the loader, the height of the robot can be adjusted. As a result the cameras looking perpendicular to the direction of travel of the tractor will be able to image the trees with apples.

Goals

Understand and implement a system that could aid a robotic fruit picking machine at distinguishing both red and green apples in an orchard.

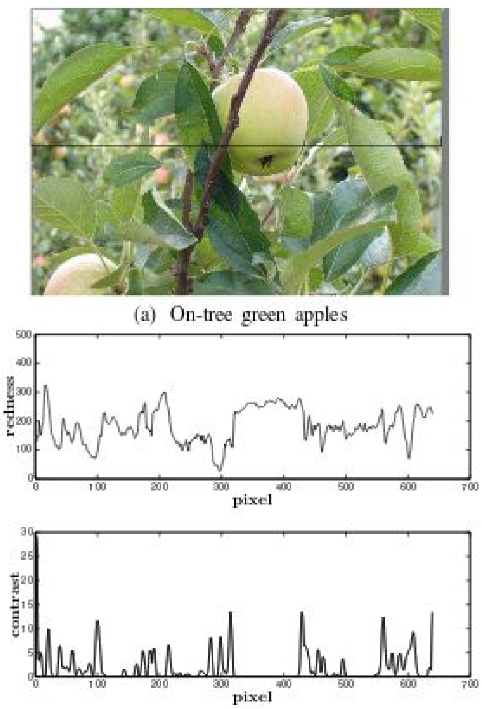
Specifications

Unlike the color, which is a single pixel based property, texture properties are based on area. The definition of three texture properties, namely; energy, entropy and contrast. Having tried these three experimentally, texture contrast was chosen as the property to be used in fruit recognition. The texture property plays two roles in the recognition procedure. First it isolates areas that have the same texture. Note that as different color regions can have the same texture it alone cannot identify apples. Secondly, an averaging technique has been used to define a quantity for each pixel which is a texture measure in the surrounding area. The texture measure is then used in an edge detection algorithm to isolate areas of same texture. In the end, it helps identify the shape of the apple and its centre.

A. Texture Measure Calculation
B. Edge Detection
C. Fruit Recognition
D. Pre-Processing
E. Post-Processing

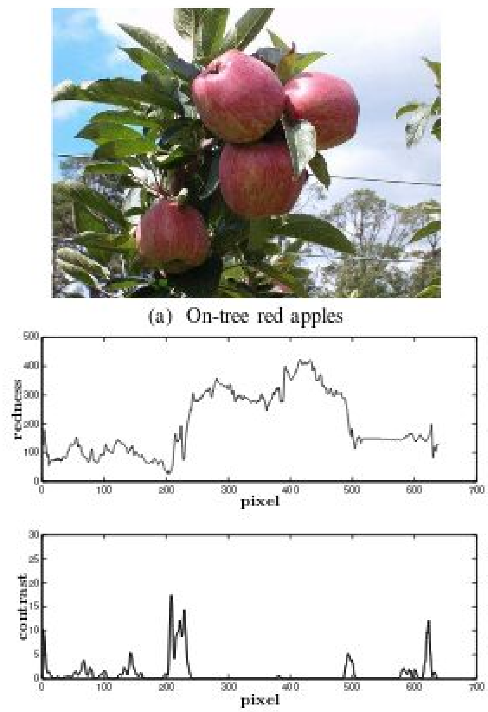
Milestones

I. Redness



(b) Redness plot of (a)

Fig. 7. Redness of green apples



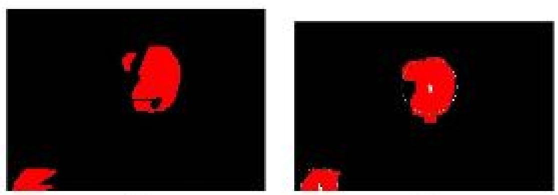
(b) Redness plot of (a)

Fig. 8. Redness of red apples

It was mentioned earlier that the redness property works equally well for on-tree green apples as well as red apples. Fig. 7(a) shows on-tree green apples and Fig. 8(a) shows on- tree red apples. For the two cases the redness and texture contrast are plotted in Fig. 7(b) and Fig. 8(b). Fig. 7(a) shows a rectangular region in the middle of the image. The color values plotted are for the centre horizontal line of pixels of the rectangle. The texture values plotted are for the same horizontal line. The plots for Fig. 8(a) were generated in a similar manner. As can be seen in both red and green apples, the redness curve produced the highest color contrast. The texture contrast shown are already filtered using ISEF. It can be seen that the texture stayed steady within an apple region at a very low value. It is readily evident that apples can be identified by combining texture contrast and redness

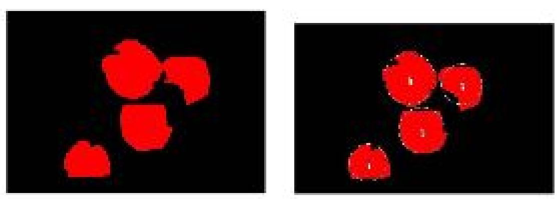
II. Green Apple Recognition

The result obtained without area thresholding and dilation and erosion, is shown in Fig. 9(a). The result with dilation and erosion, area thresholding and circle fitting is shown in Fig. 9(b). It is clear from the result that dilation and erosion significantly reduces the contour complexity and delivers a more realistic result. Further, despite the apple being green, the redness has been used to correctly identify both green apples.



(a) (b)

Fig. 9. Green apple detection using redness



(a) Connected apples (b) Separated apples

Fig. 10. Processed images of Fig. 8

III. Clustered Red Apple Recognition

Apple contours overlap. In most situations, the overlapped regions are very small. This is due to texture and color variation as the apples' surfaces curve away

IV. Laplace Filtering

The effect of using Laplacian filtering to deal with distant backgrounds that resemble apple texture and redness eliminate the undesirable result in which some parts of the background merged with some of the apples. The reason was that during texture thresholding, some of the background texture areas were retained as areas belonging to apples. As these background edges, in particular due to grass or apple leaves, lie very close to each other, the background texture changed significantly after the application of

Laplacian edge enhancing filter. Since there were no such edges within the apple areas, the texture change within the apples were minimal. This increased contrast in texture helped separate the background regions from apple regions. Once again to maintain computational simplicity, dilation and erosion was not used.

V. Distant Apples

In a robotic fruit picking scenario, it is important to take global images of the orchard and to identify the regions where fruit may be present so that cameras that may be mounted on the robot arm itself can be guided to take close up images to precisely locate the apples. No dilation and erosion is used. Given that this is a global view, it is only necessary to detect the regions where fruit may be present

Conclusion

An algorithm that can be used to recognize on-tree apples has been presented. As primary tools, it uses the texture property contrast and the color property redness. It was shown that redness works equally well for red apples as well as green apples. The contours that form boundaries of apples have been extracted using edge detection on texture images. To avoid contour shape distortion, thresholding has been carried out on contours rather than on individual pixels. The only modification that was allowed for the contour shapes were through dilation and erosion. This procedure has been followed to maintain a high accuracy of contour shape and size. To eliminate the merging of the backgrounds, edge enhancing filters have been used thereby changing the background texture while keeping the apple texture unchanged. This increased texture contrast helped identify apples separately from background. The algorithm worked equally well for close ups as well as distant images of apples.