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Fractal Analysis & Characterization of Tropical Fruits

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ABSTRACT

In this paper, tropical fruits were characterized using fractal analysis. Depending on the suitability of the fruits’ properties, contour and texture analysis were carried out in an attempt to characterize and distinguish between the fruits. The fruits used for the study were durian, pineapple, jackfruit, and strawberry.

It was found that the fractal dimensions varied with the size of the window analyzed. However, above a certain length, the value of the fractal dimensions stabilized. The minimum window required for this stable fractal dimension, as well as the value of this stable fractal dimension, was determined and tabulated for the fruits.

The results obtained showed significantly different dimensions for most of the fruits. This implies that contour and texture fractal analysis has much potential to be a tool for characterization for most of the fruits studied. For the durian and the pineapple, though, both analyses could only slightly distinguish between the two fruits.

In addition, fractal analysis of the Esplanade showed that it had very similar fractal dimensions to a durian.

INTRODUCTION

Fractal geometry can be considered as an extension of conventional (Euclidean) geometry (Smith et al., 1996) where fractals serve as mathematical models for very irregular and very detailed sets. Usually, systems of points have dimension zero and curves dimension one. In the case of irregular curves, though, fractal geometry allows measures which change in a non-integer way when the unit of measurement changes – the governing exponent, $D$, is the fractal dimension (Mandelbrot, 1982).

Fractal geometry is based on a scale invariance concept. Under magnification, shapes which appear to be smooth are more approximated by their tangent spaces. The bigger the magnification, the simpler they look. However, over some range of magnifications, magnifying the object may not portray a simple picture, but instead, repeated forms of the same kind of detail (Mandelbrot, 2002). The fractal dimension, therefore, can be used as a quantifier of complexity of form (Smith et al., 1996).

While fractals are commonly found in nature, it has to be noted that the self-similarity present in natural objects are said to be statistical self-similarity (Mandelbrot, 1982).

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This has to be distinguished from exact self-similarity present in objects such as Julia Sets, Mandelbrot set, and so on. In this study, the contours and textures of tropical fruits were investigated for fractal behaviour.

MATERIALS AND METHODS

In this study, fractal analyses were performed on two different physical properties – contour, as well as texture. 3 fruits were used as samples for each species of fruit. In determining the fractal dimension at a certain length or area, 10 data points were taken and an average was calculated.

Contour analysis

Contour analysis was carried out using the box counting method. This analysis was only carried out on the durian and pineapple since their contours are well-defined and can be observed clearly. On the other hand, the contours of the jackfruit and strawberry are too smooth to be analyzed by this method.

For this method, the photograph of the fruit (taken by a Sony Ericsson 3.2 MegaPixels CyberShot K800i) was imported into Adobe Photoshop and the contour was traced using the function ‘Find Edges’. The picture was then binarized. It was then saved and opened in ImageJ, a image-processing software. A fractal analysis plug-in, FracLac v2.4e, was used to carry out the fractal analysis.

The fractal analysis involved plotting the binary image on a screen, and all pixels belonging to the structure were counted (Barnsley, 1999). The screen was then divided into squares (2x2 pixels, 3x3 pixels, 4x4 pixels, and so on). The number of squares intersecting the structure was counted. The number of squares is taken to be $q_1$, $q_2$, and so on. The fractal dimension $D$ is given by

$$D = \frac{\log(N_r)}{\log(1/r)}$$

where $r$ is the dimension of the square, $N_r$ is the number of squares intersecting the structure, and $D$ is the fractal dimension.

By rewriting it in a linear form,

$$\log N_r = a - D \log (1/r)$$

Thus, by plotting $\log N_r$ against $\log (1/r)$, the slope yields an estimate of the fractal dimension $D$.

Texture analysis

Texture analysis was carried out on all fruits; using two different methods – the differential box counting method and the 2D variation method. Both these methods involve are based on the distribution of greyscale pixels in an image.
The photograph was imported into Adobe Photoshop and was converted to greyscale mode. The image was then saved and opened in ImageJ. FracLac was used to carry out the fractal analysis.

In the differential box counting method, the image was viewed as a 3-D space with x, y denoting 2-D position and the third coordinate z denoting gray-level (Biswas et al., 1998). The x, y space was partitioned into grids of size $s \times s$. On each grid there was a column of boxes of size $s \times s \times h$ where h is the height of a single box. Letting the minimum and maximum gray-levels of the image in the (i, j)th grid fall in box number k and l, respectively; then $n_{i,j} = k - l + 1$ is the contribution of $N$ to the (i, j) th grid where $N_r$ was counted for different values of r. Taking contributions from all grids,

$$N_r = \sum_{i,j} n_r(i,j)$$

where $N_r$ was counted for different values of r. Then using

$$D = \frac{\log(N_r)}{\log(1/r)}$$

$D$ was estimated from the least squares linear fit of $\log(N_r)$ against $\log(1/r)$.

The 2D variation method, similar to the differential box counting method, is based on the distribution of pixel intensities within the image (Karperien, 2003). It is defined as

$$D_{Bgray} = \lim_{r \to 0} \frac{\ln(I_{i,j,r} + 1)}{\ln(1/r)}$$

where $I_{i,j,r} = \text{Maximum Pixel Intensity}_{i,j,r} - \text{Minimum Pixel Intensity}_{i,j,r}$ for gray scale values at position (i,j) using boxes of size r.

**RESULTS AND DISCUSSION**

The following values were obtained:

<table>
<thead>
<tr>
<th>Object</th>
<th>Texture Analysis</th>
<th>Differential Box Counting</th>
<th>2D Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dimension</td>
<td>Minimum Window</td>
</tr>
<tr>
<td>Durian</td>
<td></td>
<td>1.408±0.014</td>
<td>40%</td>
</tr>
<tr>
<td>Pineapple</td>
<td></td>
<td>1.392±0.012</td>
<td>60 cm$^2$</td>
</tr>
<tr>
<td>Jackfruit</td>
<td></td>
<td>1.518±0.028</td>
<td>40 cm$^2$</td>
</tr>
<tr>
<td>Strawberry</td>
<td></td>
<td>1.100</td>
<td>N.A.</td>
</tr>
<tr>
<td>Esplanade</td>
<td></td>
<td>1.442±0.026</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
Table 2. Tabulation of fractal dimensions for contour analysis

<table>
<thead>
<tr>
<th>Object</th>
<th>Contour Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dimension</td>
</tr>
<tr>
<td>Durian</td>
<td>1.341±0.024</td>
</tr>
<tr>
<td>Pineapple</td>
<td>1.333±0.010</td>
</tr>
</tbody>
</table>

From the results obtained, most of the fruits had significantly different fractal dimensions. This implies that fractal analysis shows much potential to be used for characterizing purposes. However, the durian and pineapple showed very similar fractal dimensions, and other fractal measures may be necessary to distinguish between them.

Texture analysis seemed to be more reliable and convenient, especially if it is to be applied on a large scale. This is because photograph capture as well as image processing was simpler as compared to contour analysis. It is also applicable on a wider variety of fruits as it does not require the fruit to have a well-defined contour pattern. However, it is acknowledged that various fractal measures need to be used hand in hand in order to be used as an efficient tool for characterization. Improvements can be made for contour analysis if a high-quality image processing software and a high resolution camera is used.

CONCLUSION

Fractal analysis shows much potential as a tool for characterizing fruits. In order for a characteristic fractal dimension to be obtained for a particular fruit, the length or area of the image studied must be above a certain cut-off value. One method of fractal analysis alone may be unable to differentiate between two fruits; more methods must be used in conjunction with each other for this purpose. This is especially so for fruits sharing similar geometry such as the durian and the pineapple. On a final note, analysis of the Esplanade gave a very similar fractal dimension to the durian compared to other fruits.

REFERENCES


(b) Karperien Audrey, FracLac v2.4e for Image J
    http://www.geocities.com/akarpe@sbcglobal.net/usefraclac.html (last accessed 01/10/2007)
