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Particle-Like Fractal Images for Testing Algorithms that Measure Boundary Fractal Dimension.

D. S. Bright

Surface and Microanalysis Science Div., Nat'l Inst. of Stds. and Technology, Gaithersburg, MD. 20899-8371

In order to test image processing tools that measure the boundary fractal dimension, Db, of particles, I made sets of digital images of computer generated particle-like fractal objects having a large range of Db and shape. These images are available on the web [1]. Another paper in this proceedings [2] gives the description of the family of fractal objects – this paper describes how digital images were made from them and how they were used to test two methods that measure Db.

A variety of methods for measuring Db are in the literature [3]. It is always desirable to test a method before using it, as the methods have differing accuracies and ranges usefulness. These sets of images allow for testing methods more thoroughly than previously, because many fractals are available with finely spaced values of Db, and with a variety of shapes for any given Db.

Although Db for these computer generated geometric or mathematical figures can be determined most precisely from a list of coordinates of their edges, it is more useful to construct digital, and measure the fractal dimension of their boundaries in the same manner that the user would measure Db for micrographs of particles, that is by thresholding the images, blobbing them, and tracing the outline. This outline, running around the edges of the pixels of the object, is then used to determine Db.

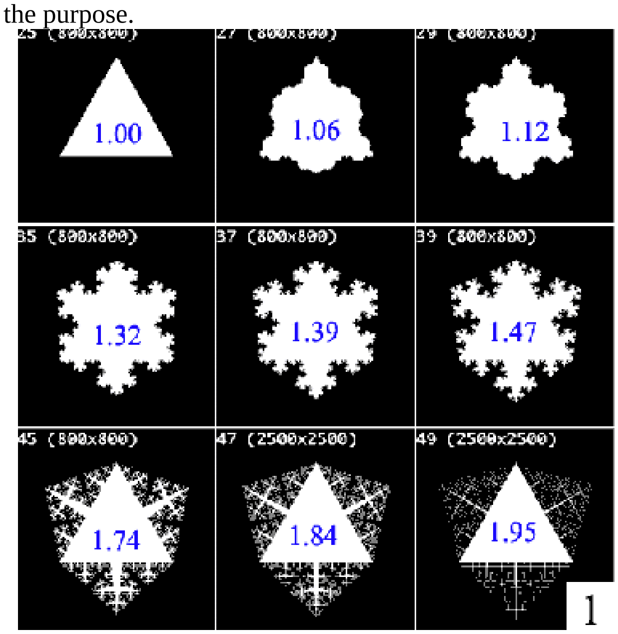
Figure 1 shows a series of fractals that change in shape, and range in Db from 1.0 to 1.95. These range in shape from the triangle, through the standard Koch snowflake, to a triangle again with very fine, tightly packed spikes. Figure 2 shows another series of fractals, all with Db = 1.2, but with shapes ranging from cauliflower like to a triangle with sharp spikes.

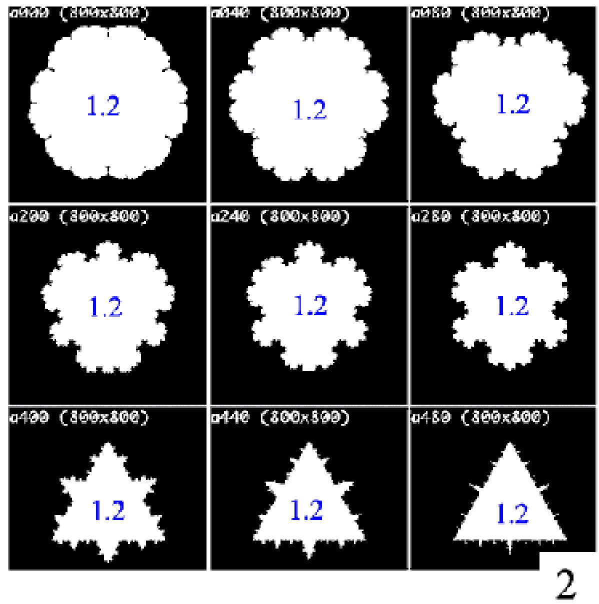
Figure 3 shows local Db as a function of the dimension used when generating the fractals. The Db is local because it was measured [1] for a specific step length, or scale. Fractals have the same Db at any scale, but these digital images have a restricted scale range for which the Db is valid, due to restrictions in rendering them. Db was measured with the coordinate averaging method [4] and the dilation / distance map method [5,6]. The coordinate averaging method is accurate over the whole range of D – this is possible because the images are constructed to appropriate scales so that spikes on the high Db fractals do not touch each other. The dilation method does not perform as well, but is more popular because the functions needed to perform it are in most off the shelf image processing systems. The deviation of the last point (Db = 1.95) is due to a few of the interior spikes touching their neighbors. Figure 4 shows the local Db for two scales, determined by the coordinate averaging method. These images were rendered all at the same scales and resolutions (image sizes), as a more honest simulation of real particles. The measured Db ranges from 1.18 to 1.22, except for the cauliflower shapes (Fig. 4, top left), where some of the true perimeter is buried in the small crevices and is not traced by the image processing algorithm. In these cases, the measured Db can be expected to be off, and the images are not included in the test image sets.

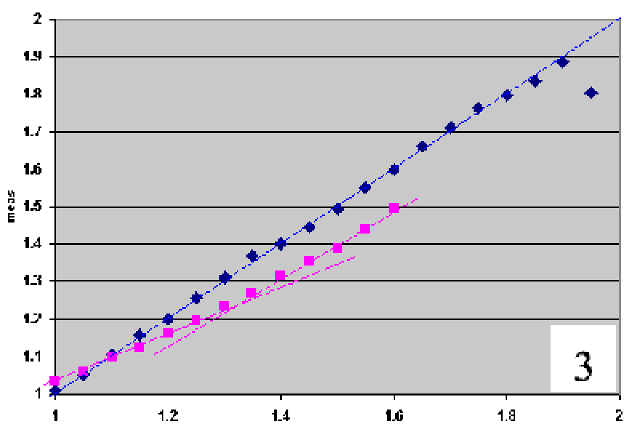
The images shown here are a sample of the available fractal image sets, which should prove useful in evaluating image processing software that measures the local boundary fractal dimension of particles.

References:
1. Test images and image processing software available from author at: www.nist.gov/lispix.
2. D.S. Bright, “Families of Particle-Like Fractals…”, (this proceedings).
3. M. Allen et al, Powder Technology 84 (1995) 1-14.
4. J. Adler & M. Allen, Part. Prt. Syst. Charact 11 (1994) 418-425.
5. J. Adler & D. Hancock, Powder Technology 78 (1994) 191-196.
6. Russ, J.C., THE IMAGE PROCESSING HANDBOOK, 2nd Ed, CRC Press (1995).

* Certain commercial equipment, instruments, or materials are identified in this report to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.







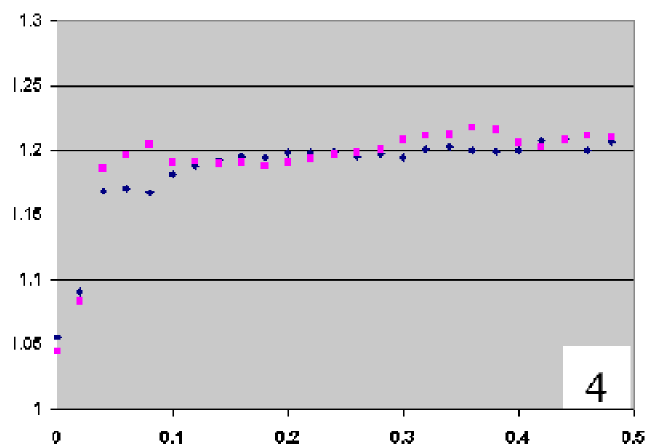


FIG. 1. Thumbnails of fractals spanning almost full range of Db (blue). Note – fractals with high Db rendered larger, but to less resolution – the smallest edges are 20 pixels long rather than 4 pixels.
FIG. 2. Thumbnails of fractals, Db = 1.2, shape parameter a = 0.0 to 0.48. Cauliflower shapes at upper left - fractal nature hidden in crevices and not rendered in digital image, measured Db to small.
FIG. 3. Db, for step length 34 pixels, vs. Db generated. Blue – coordinate averaging. Pink – dilation / distance map. Blue line, ideal. Pink lines – manually drawn to show smaller useful range.
Fig. 4. Db, coord av. method vs. Db, generated. Step lengths blue – 30, pink – 70 pixels.

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