

BLUE NOISE MASK

PREMIER STOCHASTIC IMAGING TECHNOLOGY



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University of Rochester



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Blue Noise Mask

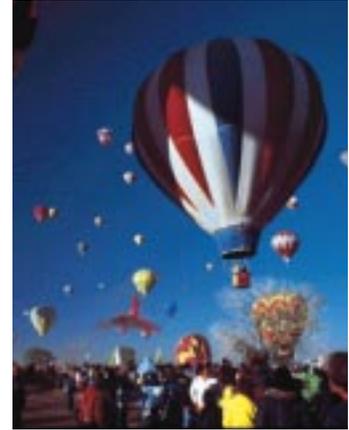


IMAGE ENHANCEMENT

UNTIL THE LAST DECADE, high-quality digital halftones required an inordinate amount of time to print. In 1991, after years of development, the BLUE NOISE MASK technology changed the face of digital halftoning. The benefits of this revolutionary technology became more pronounced with the advent of color halftoning and multicolor printing.

BLUE NOISE MASK Development

Necessity is the mother of invention, and the BLUE NOISE MASK is no exception. In the late 1980s, researchers Kevin Parker and Theophano Mitsa of the University of Rochester developed the technology to provide high-quality halftones several times faster than the best algorithms available.

Dr. Parker, an expert in imaging, wanted to improve the quality and production time of digital printouts from diagnostic equipment. Researchers often were unable to determine whether a spot on a medical image was an incipient tumor or merely an artifact added to the image during printing.

The algorithm designed by Parker and Mitsa combines the superior imaging benefits of error diffusion halftoning techniques with the high speed and low complexity of other well-known halftoning methods.

Halftoning Process

Printing industry professionals know that the halftoning process applies to technologies that can create only black and white dots, such as printers, printing presses, imagesetters, monochrome computer displays and similar systems.

The process creates the illusion of gray by varying the density and arrangement of black dots on a white background. To accomplish this, a computer processes sets of pixel (picture element) gray-level values on a grid and calculates which numbers represent black printer dots and which numbers represent white printer dots. Each pixel has a number from 1 to 256 that represents the gray-scale (brightness) value. The numbers are compared against a threshold gray-level value; the threshold values are placed in a halftone mask. Pixels with values below the threshold represent black dots while those equal to or greater than the threshold represent white dots.

The threshold technique is the primary mechanism used in today's computer halftoning. A halftone mask is often referred to as a *threshold array* among imaging engineers. Different halftoning processes create different results. Figure 1 shows several well-known configurations. Figure 2 conveys the advantages of the BLUE NOISE MASK technology over the other methods.



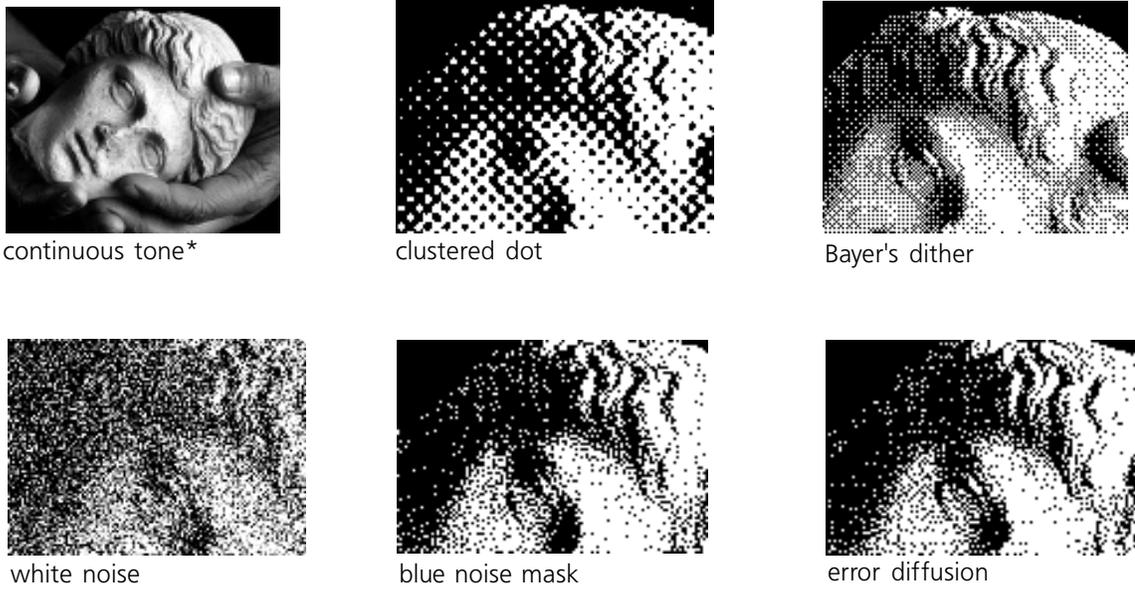


FIGURE 1 The images above show the magnified dot patterns that result from several methods that exist to generate halftones. Most halftoning methods are based on either neighborhood or point algorithms. Neighborhood algorithms—used in error diffusion, for example—result in good image quality with less obvious artifacts but require extensive computations and increased production time. Point algorithms use faster computations and are suitable for most output devices, but images usually suffer from periodic artifacts and false contours. The BLUE NOISE MASK technology employs a point algorithm designed to minimize artifacts and can be implemented digitally or optically.
**Note - no halftoning in a true continuous-tone image.*

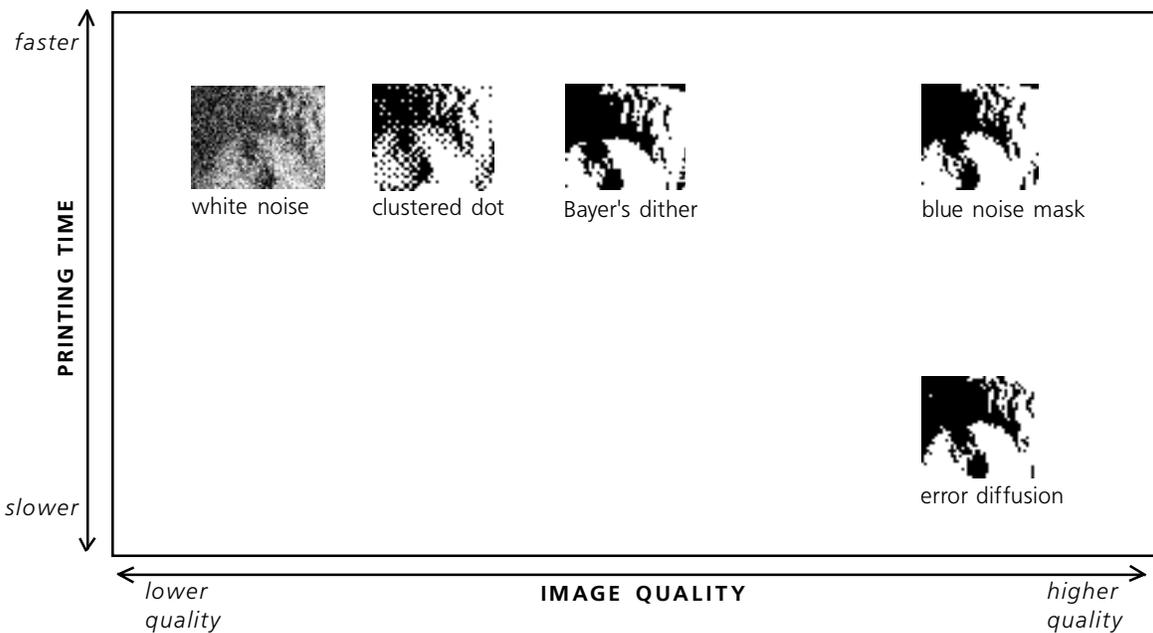
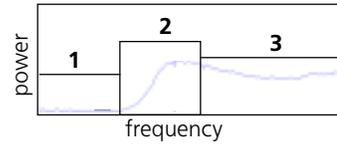


FIGURE 2 Advantages of the BLUE NOISE MASK over other halftoning methods include higher quality images and faster printing capabilities.

Average Power Spectrum

The characteristics of dot profiles produced by halftone masks can be described, in part, by a mathematical construct known as an *average power spectrum*. This spectrum is a gauge of the average frequencies contained in a dot profile. The *frequency* refers to a measurement of the closeness of the dots in a particular pattern. Low frequencies cause clumping to occur in various areas, yielding a less uniform result. The BLUE NOISE MASK filters out the low frequencies, which reduces the amount of coarse-grained clumping that occurs (Figures 3 and 4).

FIGURE 3 A type of BLUE NOISE MASK signature.



You know it when you see it.

- Region 1: negligible or small low-frequency power
- Region 2: transition area; amount of power increases
- Region 3: high-frequency (blue-noise) power lacking dominant spikes that indicate the presence of artifacts

By reducing the low frequencies, the BLUE NOISE MASK creates a visually pleasing effect, as shown by the three blue-noise dot profiles in Figure 5.

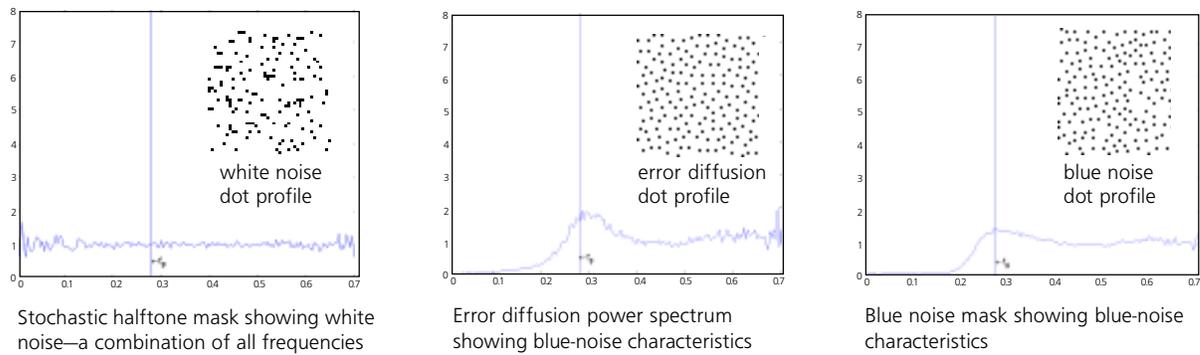


FIGURE 4 Three examples of dot profiles and corresponding power spectra.

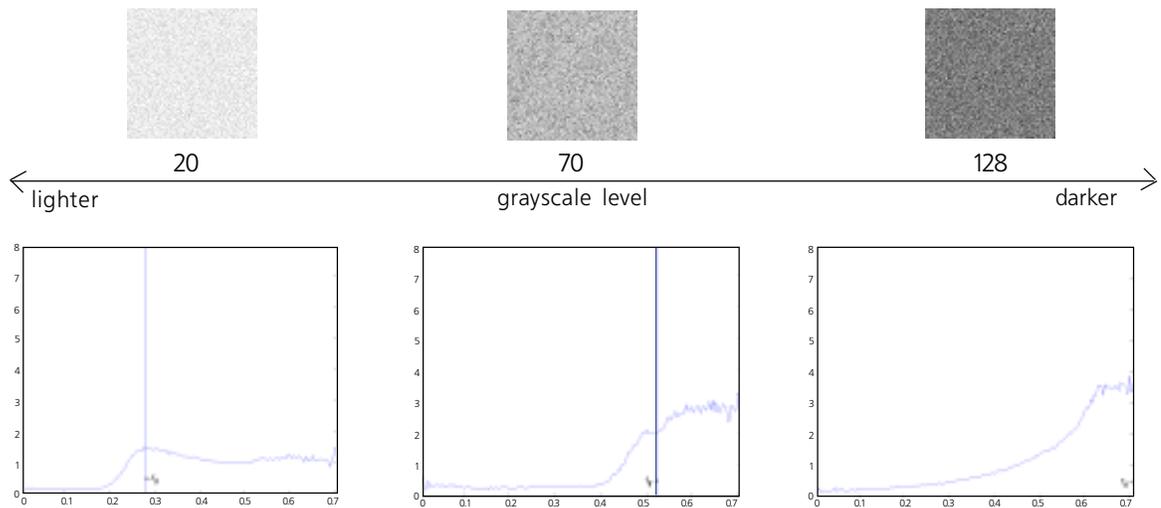


FIGURE 5 Typical blue-noise dot profiles (top) and corresponding typical radial average power spectra (bottom).

BLUE NOISE MASK and Color Printing

All colors can be created using the primary colors of cyan (C), magenta (M), yellow (Y) and black (K). When full-color images are separated into their primary colors, each color image undergoes the halftoning process in the same manner as a grayscale image (Figure 6). Devices with the BLUE NOISE MASK allow for virtually instantaneous halftoning and produce high-quality color images at affordable costs.

BLUE NOISE MASK Key Features

- Produces high-quality images at faster speeds, eliminating computations required in other high-quality digital halftoning techniques.
- Produces fewer recurrent patterns than ordered-dithered methods.
- Free of scanning and start-up artifacts often seen in error-diffusion techniques.
- May be implemented in software and hardware.



cyan



yellow



magenta



black

FIGURE 6 Four-color halftone separation.

BLUE NOISE MASK Applications

- Desktop publishing systems
- Digital cameras
- Digital halftoning for graphic arts
- Fax machines
- Ink-jet and laser printing
- Medical and scientific imaging
- Photocopiers
- Pre-press
- Web products
- Wide-format printing
- Video games

RCT invites you to add your company to the list of Blue Noise Mask licensees.

BLUE NOISE MASK Benefits

- Quality
- Adjustability
- Minimal artifacts
- Minimal moiré patterns
- Color enhancement
- Speed
- Simplicity

Worldwide Patents

Research Corporation Technologies (RCT) has developed a formidable portfolio of patents covering the BLUE NOISE MASK technology.

The estate includes six U.S. patents and one Japanese patent (listed below). Several European patent applications have been allowed and will issue soon.

RCT Blue Noise Mask Patent Estate

U.S. Patent Nos.:

- 5,726,772
- 5,708,518
- 5,543,941
- 5,477,305
- 5,341,228
- 5,111,310

Japanese Patent No. 2,622,429.

Licensing Opportunities

RCT has licensed its BLUE NOISE MASK technology to several companies, including Hewlett-Packard, Lexmark and Seiko-Epson, in settlement of infringement lawsuits.

BLUE NOISE MASK — Premier Stochastic Imaging Technology