Pseudo-Random Halftone Screening

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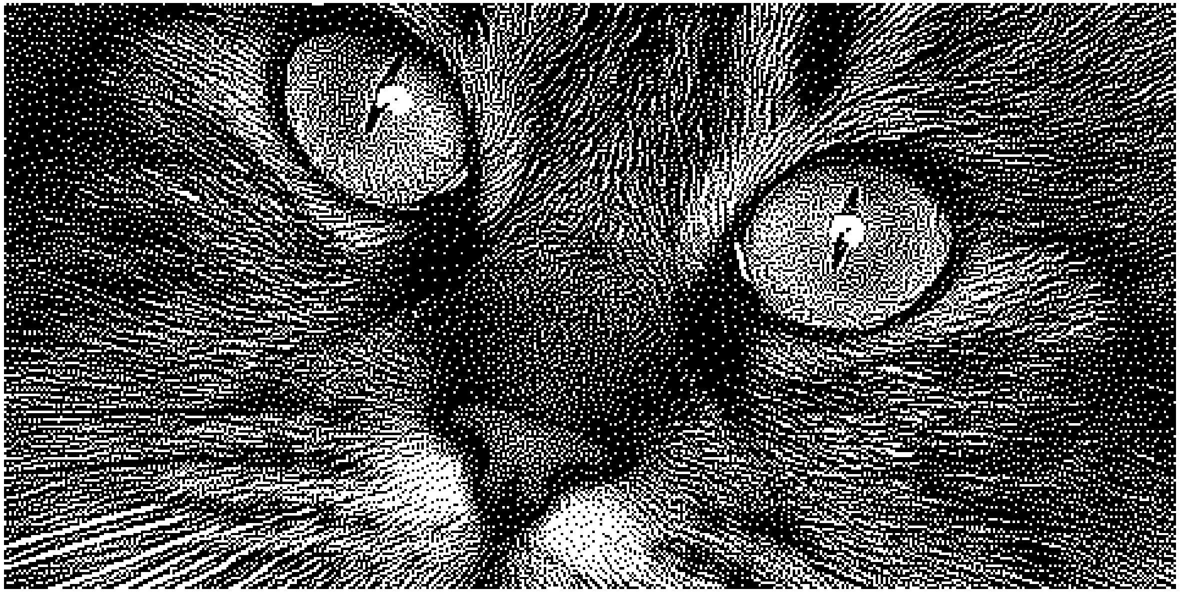
What is halftone image?

An image is only composed from pure white and pure black color.

As is shown in the below picture. It is widely used in printing.

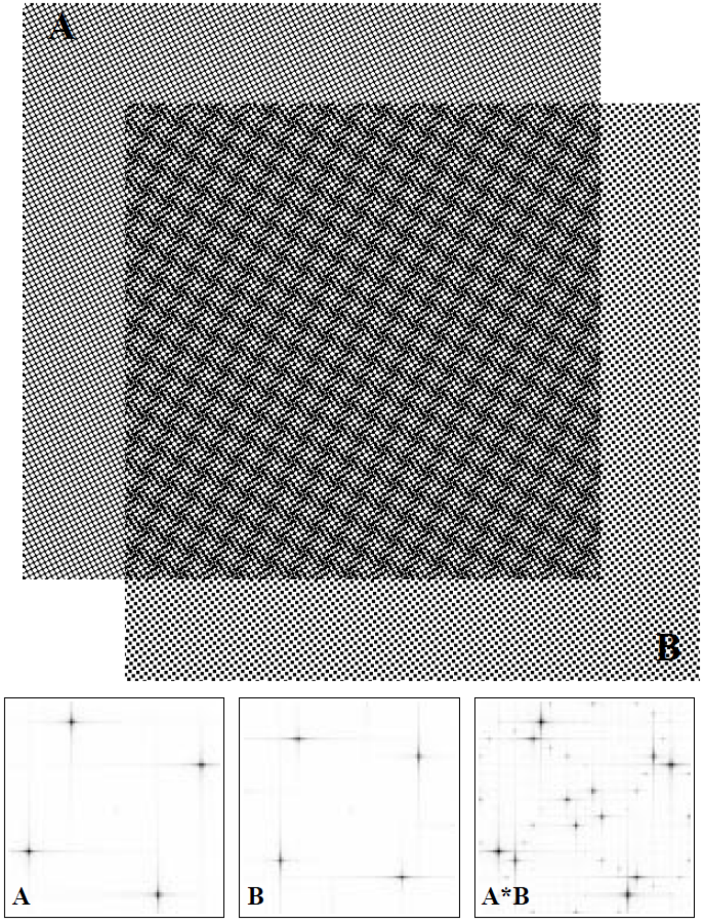


Limitation of traditional approach

When two structures are superimposed, the Fourier spectrum of the resulting structure is the convolution of two Fourier spectra of two images.

The right picture shows that two regular superimposed structures has the phenomenon perceived as the Moire fringe(莫尔条纹).

At low-resolution, different error-diffusion techniques with symmetrical spectra are widely used. But the error-diffusion technique cannot be used in conventional high resolution printing because of important dot gain due to ink spread.

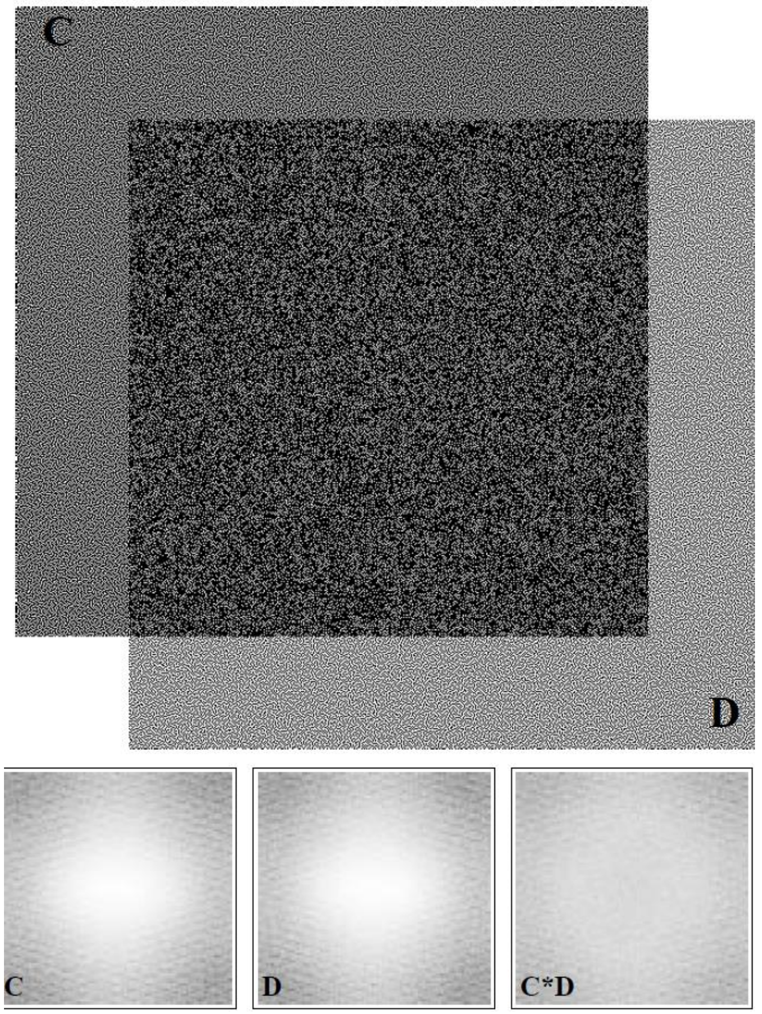


Traditional approach

Limitation of traditional approach

In the case of two pseudo-random superimposed structures C and D shown in the right figure, the resulting Fourier spectrum shown in figure 2b has no “parasite” Moire frequency.

Thus it create a good basis for building an alternative solution to conventional regular screening for color printing purposes.



Pseudo Random Screening

The first step in building pseudo-random tiling is to find a stochastic distribution of centers.

We consider each center to be related to all its neighbors by a repulsive string whose force is defined as $F = \dfrac{a}{r^k}$.

Where r the distance between two centers, k is the power law, and a is the string's strength. The neighbors are defined in the Voronoi sense.

1. The centers are randomly distributed, as well as the strengths of the strings.
2. We choose randomly to move one center; then we calculate the resulting force caused by all neighbors and displacement which is proportional and oriented in the sense of the resulting force. The neighbors are recalculated too.
3. Choose another random center and do 1 and 2. After a certain number of iterations the system becomes stable.

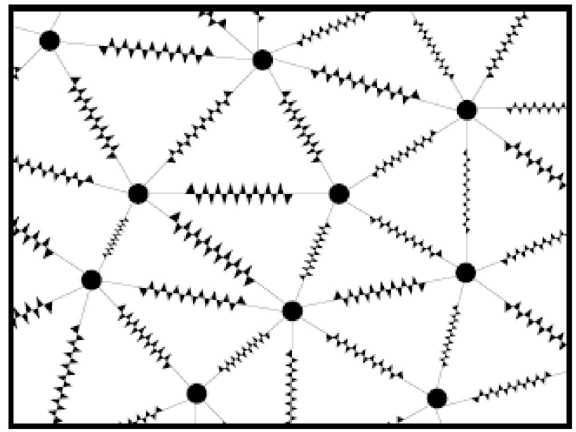
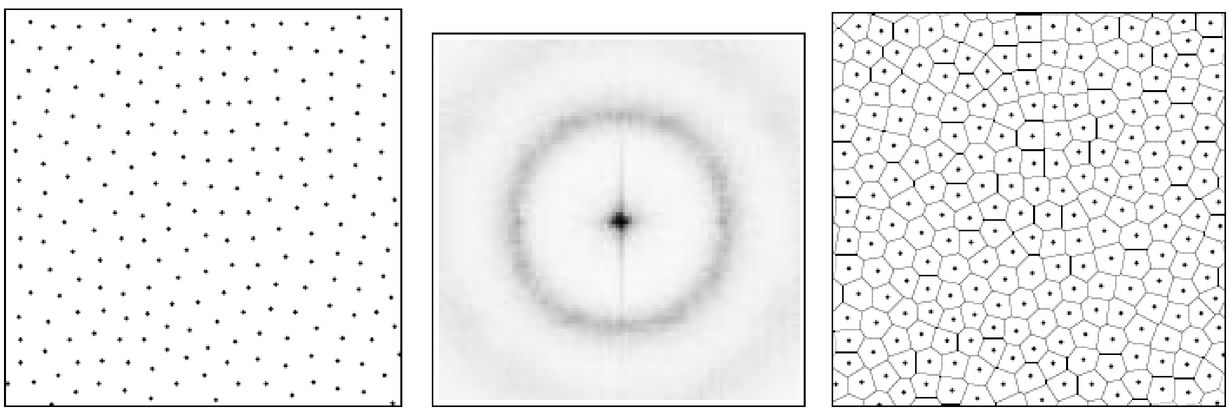


Fig. 3 Model of stochastic distribution of Voronoi polygons centers.



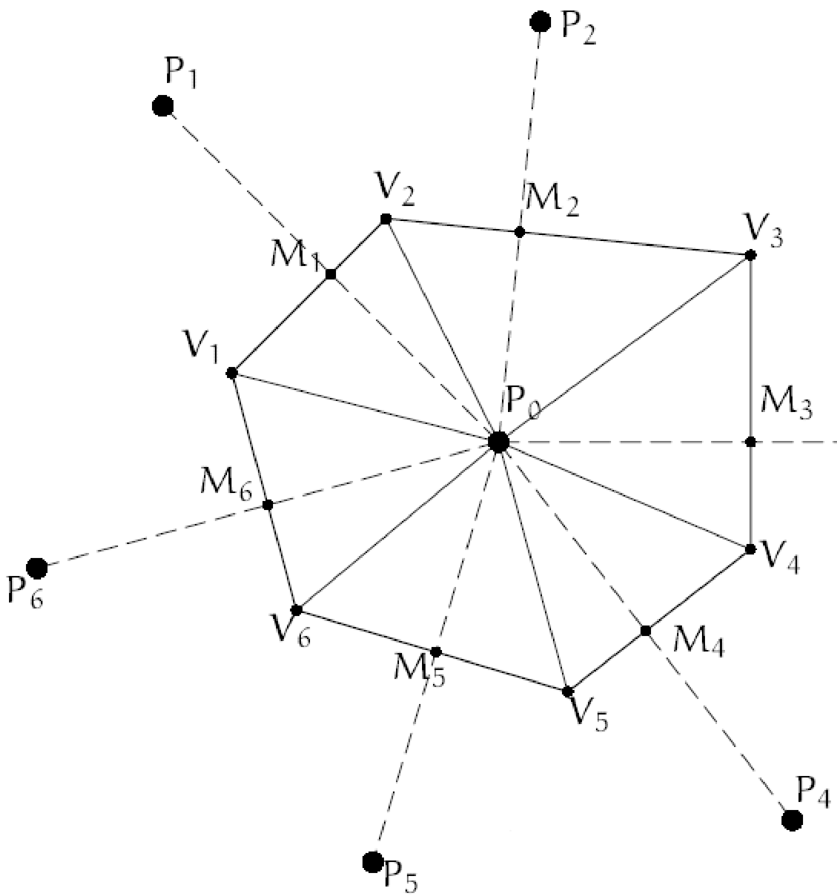
a) b) c)

Fig. 4 Final distribution of Voronoi polygon centers (a); its Fourier amplitude spectrum (b) and the resulting Voronoi diagram (c).

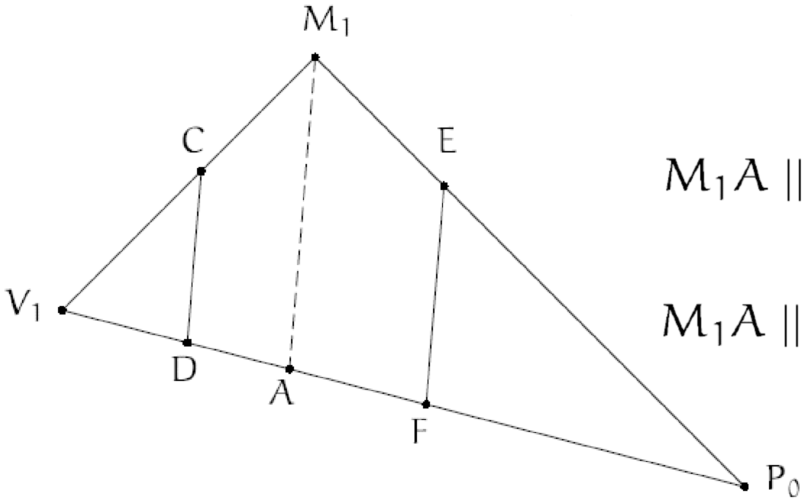
Image generation. First approach: resampling

$$g(x,y) = g(i,j) + \Delta x(g(i+1,j) - g(i,j)) + \Delta y(g(i,j+1) - g(i,j))$$
$$+\Delta x \Delta y(g(i,j) - g(i+1,j) - g(i,j+1) + g(i+1,j+1))$$

$$(\Delta x, \Delta y) = (x,y) - floor(x,y)$$



$$\frac{AP_0}{V_1A} = k \quad \Longrightarrow \quad \frac{\mathrm{Surface}(\Delta_{M_1AP_0})}{\mathrm{Surface}(\Delta_{M_1V_1A})} = k$$



$$M_1A \parallel EF; \quad \frac{P_0F}{P_0A} = m \implies \frac{\mathrm{Surface}(\Delta_{P_0EF})}{\mathrm{Surface}(\Delta_{P_0AM_1})} = m^2$$

$$M_1A \parallel CD; \quad \frac{V_1D}{V_1A} = n \implies \frac{\mathrm{Surface}(\Delta_{V_1CD})}{\mathrm{Surface}(\Delta_{V_1M_1A})} = n^2$$

For a given gray level $g(x,y) \leq k$, we can calculate the m ration;
for a given gray level $g(x,y) > k$, we calculate the n ration.
The calculated result is shown below. (Here we choose k = 3/4)

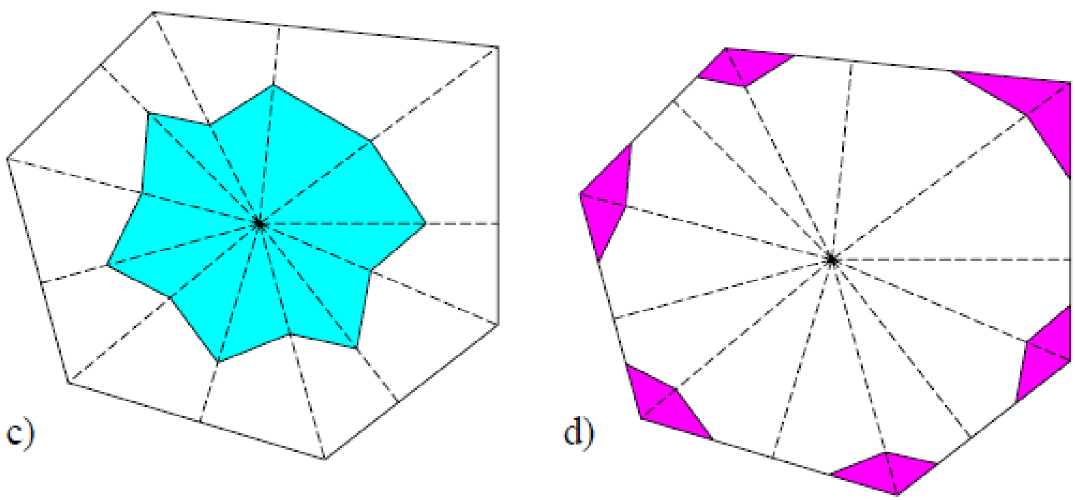


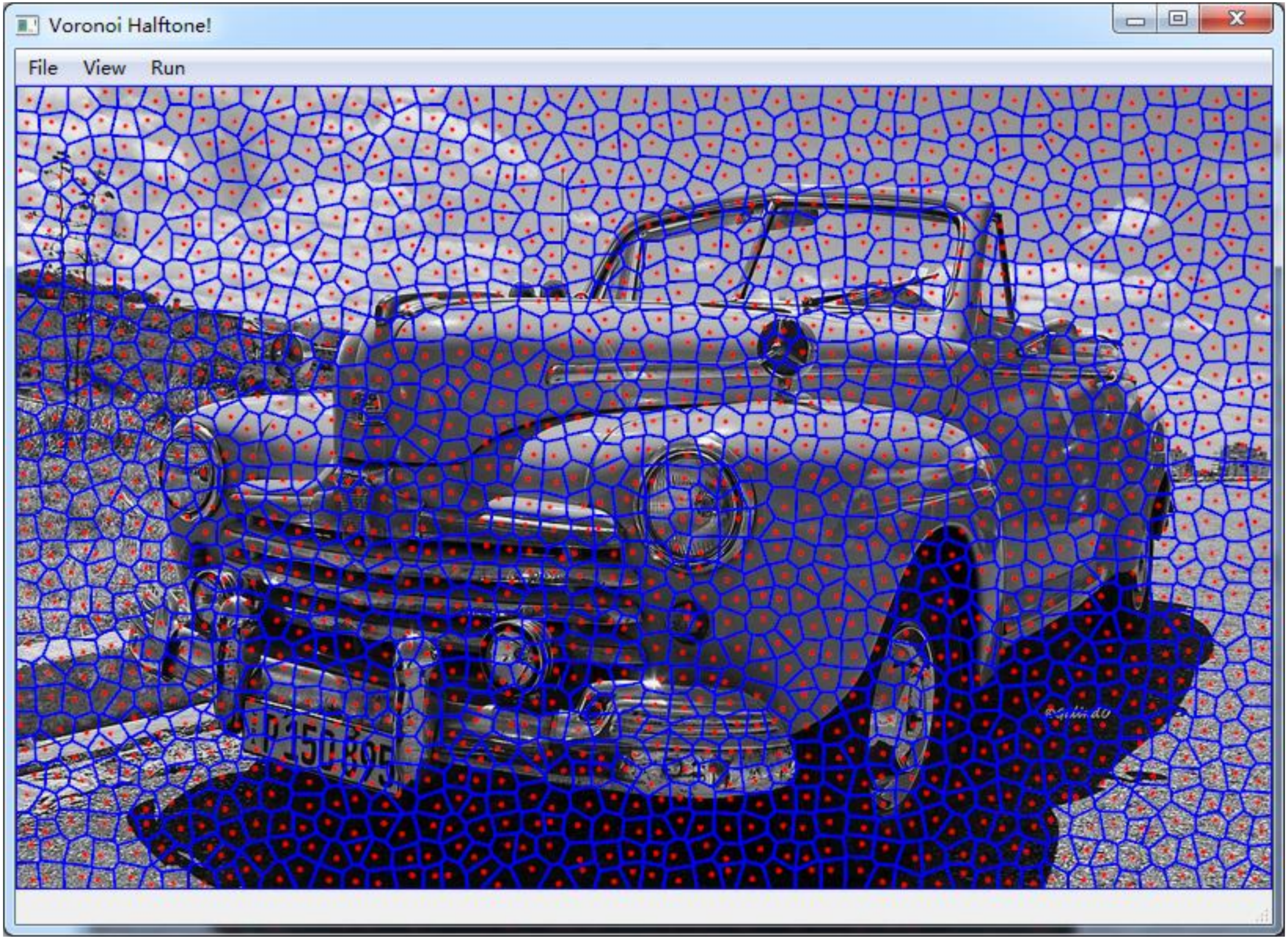
Fig. 5 Typical Voronoi polygon (a), significant triangle (b), resulting analytical curve in the case where $g(x, y) \leq k$ (c) and in the case where $g(x, y) > k$ (d).

Calculated result using our method.

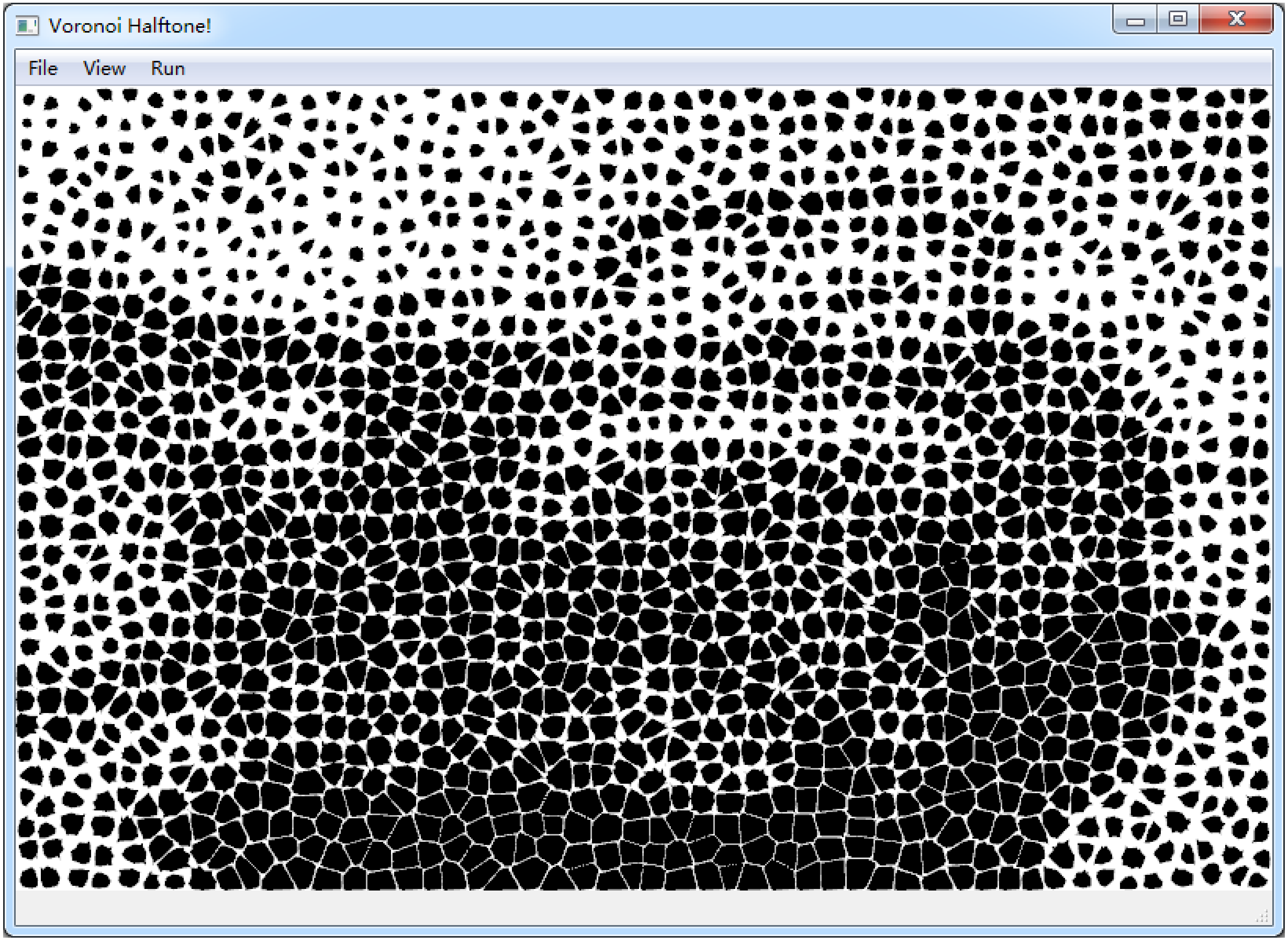
Image loaded and transformed to grayscale

Generating random sites (sparse)

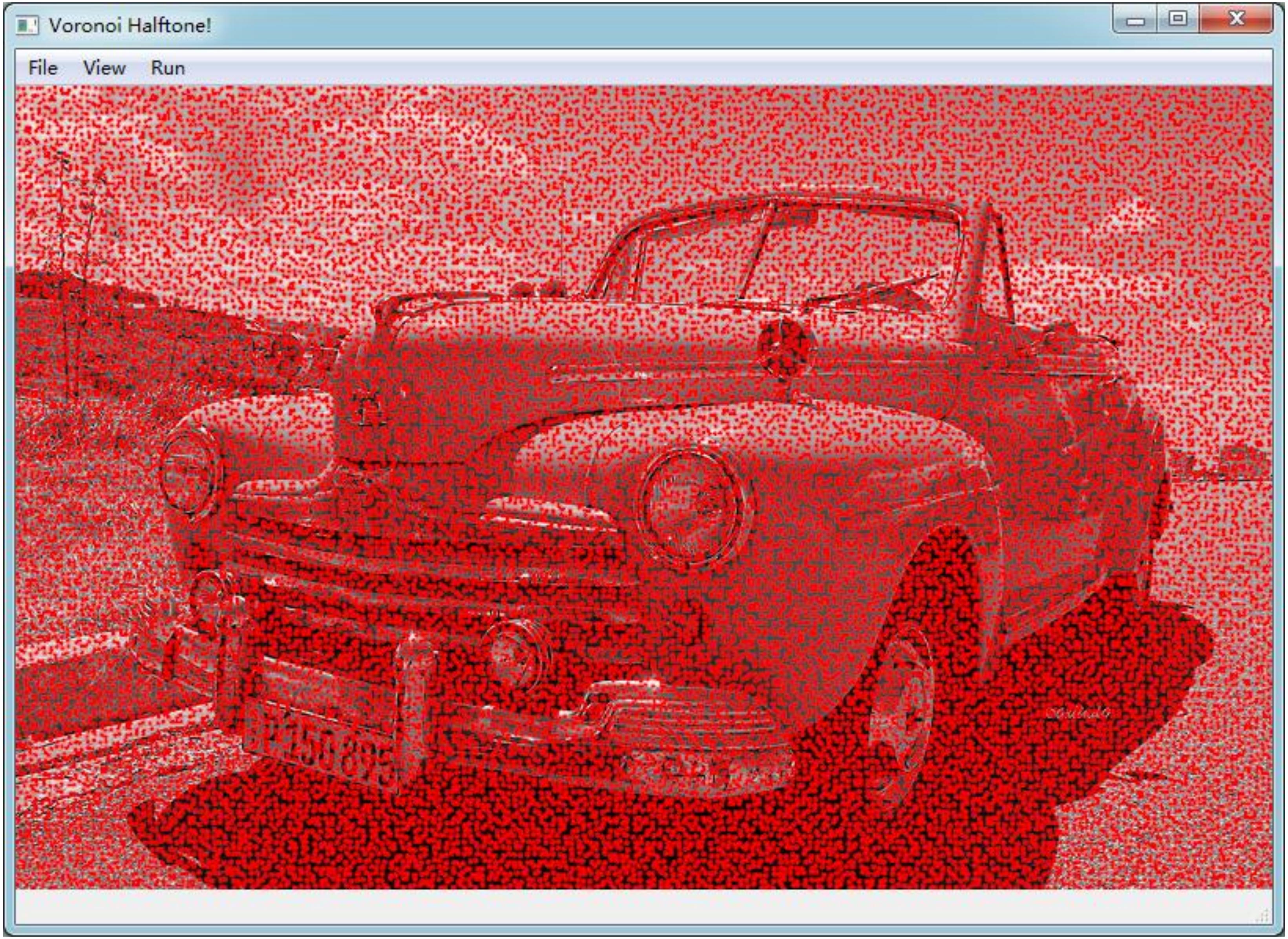
Voronoi edge with sites (sparse)



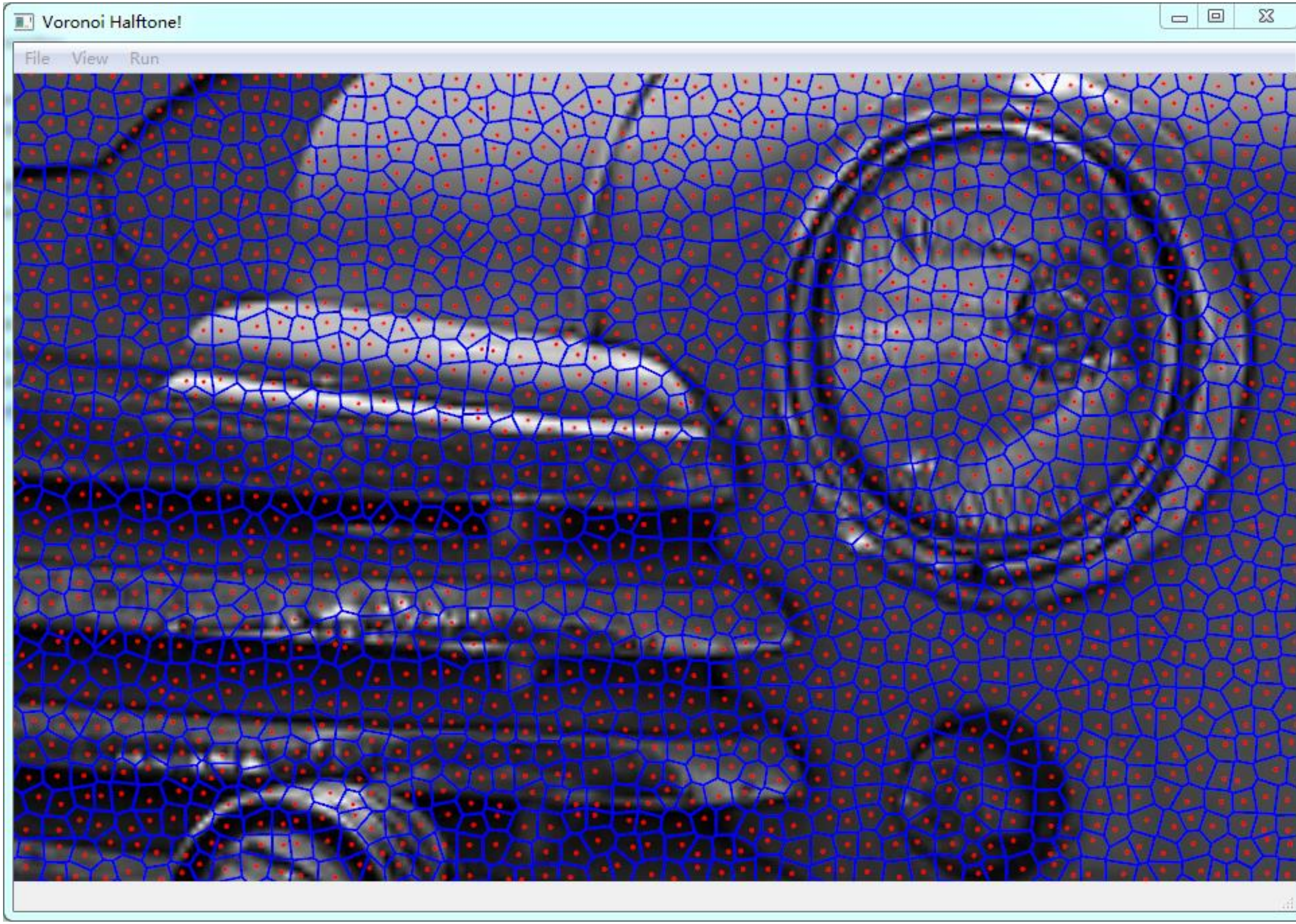
Halftone image (sparse sites)



Generating random sites(dense)



Voronoi edge with dense sites(viewport scaled up)



Halftone image (dense sites)

Conclusion

The pseudo-random halftone screening technique described in this article can be used to **faithfully** reproduce gray scale images while guaranteeing the **desired spectral characteristics**. Fourier spectra of bilevel images rendered with this technique have symmetrical well-distributed figures shaped as a ring or bell. When such a rendering technique is applied in the color printing process, the Moire effect can be avoided. Other possible application domains of pseudo-random halftone screening are fax machines, scanners and other regular-matrix raster devices.

Unlike known error-diffusion techniques, the pseudo-random halftone screening technique can be applied in a **high resolution printing** process.