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Application of Fractal Theory to Radiographic Screen-film Graininess

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The more sensitive screen-film systems are very useful for the reduction of radiation hazard. With the increase of noise by the more sensitive systems,the graininess of the X-ray film must not be neglected. For the purpose of evaluation of the graininess of the X-ray film,a new method by fractal dimensions was proposed and compared with the conventional method by Wiener spectrum. The fractal dimensions of graininess of different sensitive screen systems were determined with appropriate equipment.The Wiener spectral densities at the frequency were measured with the form $1/f^n$. The fractal dimensions of graininess had close relationship to the positive power n's. The relation between the new method and the conventional method was also investigated with computer simulations.

An increase in sensitivity of screen-film system is always accompanied by an increase of image noise. Which is composed additively of the intrinisic film graininess,the screen mottle, and X-ray quantum noise (Fig.1). The total noise of screen-film system is visualized as fluctuation of film density (Rossman: 1963). For the evaluation of the film noise,a new method using fractal dimension is proposed and compared with the conventional method by Wiener spectrum (Doi,K et al:1982). The fractal

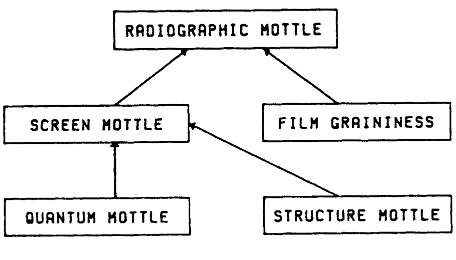

Fig.1 Constituent of image noise with screen-film systems

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dimension and Wiener spectrum of fluctuation density curves obtained from two different sensitive screen-film systems were determined. Also, the results from computer simulation of graininess were reported.

SCREEN-FILM SYSTEM

The geometrical arrangement of X-ray tube and screen-film system is shown in Fig.2. Film was located at a distance of 400cm from focus of the X-ray tube,and was uniformly exposed. The conditions of exposure were tube voltage 73Kv,tube current 120mA,and exposure time 60 or 80msec. The screen-film system consists of a X-ray film set between a front and a back screen (Fig.3). By absorbing X-ray radiation, phosphor in the screens fluorescents and emits light to which the film is exposed. Two different sensitive types of screen-film systems were used (Tab.1).

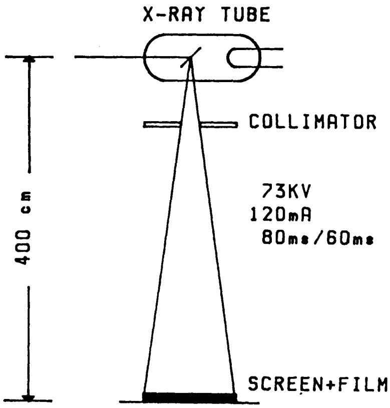

Fig.2 Geometrical arrangement of X-ray tube and film

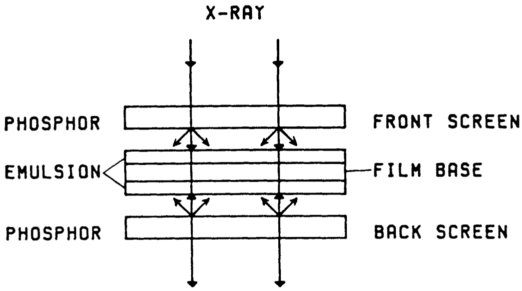

Fig.3 Schematic diagram of screen-film system

Tab.1 Combination of screen -film system A and B

SYSTEM	SCREEN		FILM
		PHOSPHOR	
A	LT-II	$CaWO_4$	SAKURA A
B	LANEX MEDIUM	Gd_2O_2S	KODAK OG-1

FRACTAL DIMENSION AND WIENER SPECTRUM

Film density D is defined as

$$D=\log(I_0/I_1) \qquad (1)$$

where, I_0 is incident light intensity,and I_1 transmitted light intensity (Fig.4). When film samples are scanned with a very narrow and long measuring slit,records of the fluctuation in film density are obtained (Fig.5) (Kuhn:1983). Fig.6 shows Block diagram of system measuring the fluctuating density curve obtained with the microdensitometer. Fractal dimension was obtained from analog curves. Fig.7 shows the measuring principle of fractal dimension. We set deviders to a prescribed opening, and move these deviders along the fluctuating density curve,each new step starting where the previous step leaves off. The number of steps are plotted against yardstick length on a doubly logarithmic scale. The straight lines are drawn by least square fits of experimental data points (Mandelbrot:1982,Musha,T:1980).

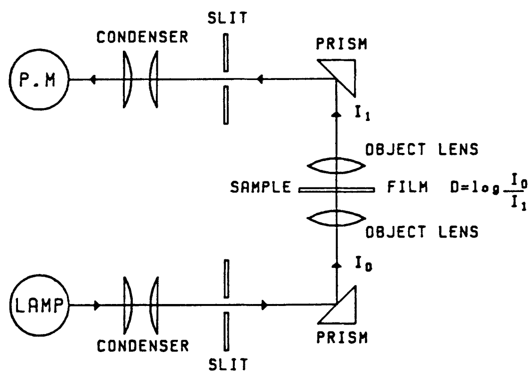

Fig.4 Schematic drawing of read out system of density fluctuation of X-ray film,namely microdensitometer

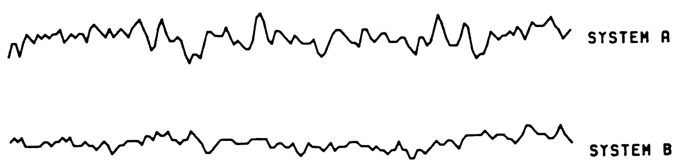

Fig.5 Film density fluctuations of a homogeneously exposed X-ray films , the upper curve is that obtained from system A and the lower curve from system B

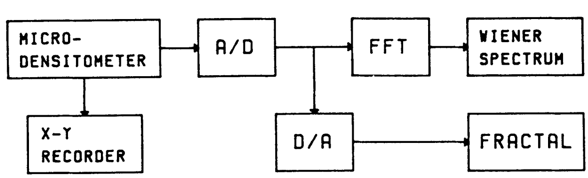

Fig.6 Measuring of Fractal dimension and Wiener spectrum

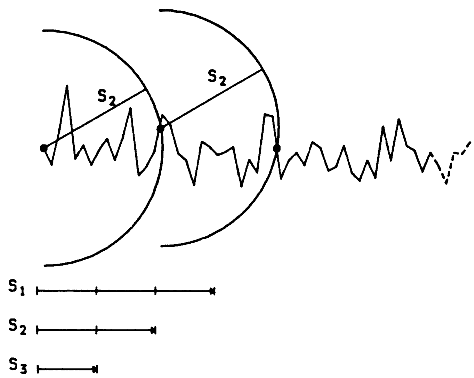

Fig.7 Measurement of Fractal dimension

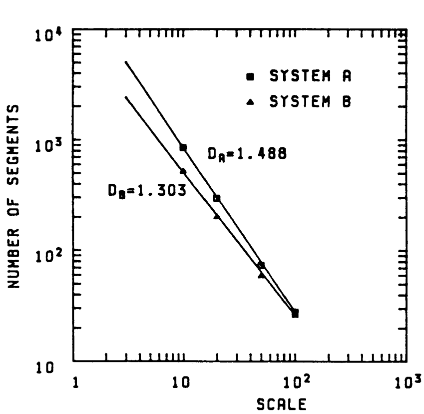

Fig.8 Fractal dimension of system A and B

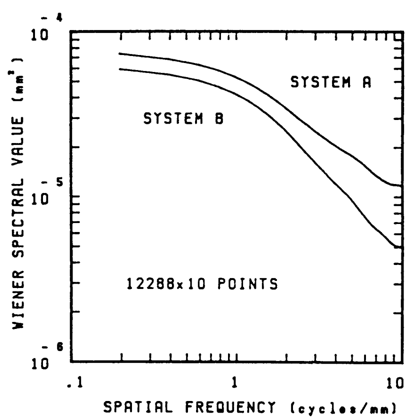

Fig.9 Wiener spectra of system A and B

Fractal dimension is defined as the slope of the straight line. Fig.8 shows fractal dimension of system A and system B. Fractal dimension of system A is 1.488 ,while fractal dimensions of system B is 1.303. By comparing these two values, it's inferred that fluctuating curve of system A is more complex than that of system B. Wiener spectrum density was obtained by performing a fast fourier tansformation of the fluctuating density curve which was converted into digital signals after rejecting aliasing errors. Let D(x) is a film density at point x. In terms of the average density D and the fluctuating component $\Delta D(x)$.
We can write

$$D(x) = \bar{D} + \Delta D(x) \qquad (2)$$

The Wiener spectrum $\Phi(u)$ of radiographic noise in terms of density fluctuations is defined by

$$\Phi(u)=\lim_{X\to\infty}\frac{1}{2\cdot X}\overline{|F(u)|^2} \quad (3)$$

where
$$F(u)=\int_{-X}^{X}\Delta D(x)\cdot\exp(-2\pi iux)dx \quad (4)$$

Fig.9 shows the Wiener spectra of system A and system B. Wiener spectrum of system A is larger than that of system B. From a comparison between Fig.8 and Fig.9, it can be seen that fractal dimension decreases with the increase of slope of Wiener spectrum.

COMPUTER SIMULATIONS

Fig.10 shows the fluctuating curves, obtained from computer simulation of graininess by generating a reciprocal of spatial frequency f to the n-th power($1/f^n$) type noise with a micro computer. Five curves represent the cases of exponent n=0, 0.5, 1.0, 1.5, and 2.0.
Fig.11 shows Wiener spectra of the preceding, fluctuating curves. Number of samples are 512 data points. Wiener spectra fluctuate, because the number of sample are few, but we can verify the forms of a reciprocal of f to the n-th power ($1/f^n$) noise, (Musha, T: 1980). Fig.12 shows fractal dimensions of the preceding fluctuaion curves. Fractal dimensions of exponent n=0, n=1, and n=2 are 1.691, 1.432 and 1.185, respectively. It can be seen that Fractal dimension increases with the decrease of exponent n of $1/f^n$. Data points fitted into a straight line, respectively. Fig.13 shows relationship of fractal dimension D and exponent n of Wiener spectrum, where n=6.145-3.564D.

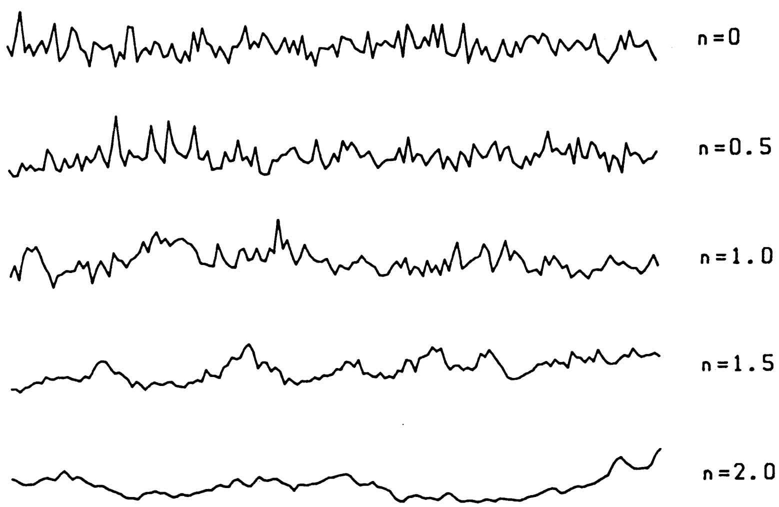

Fig.10 $1/f^n$ noises by computer simulation

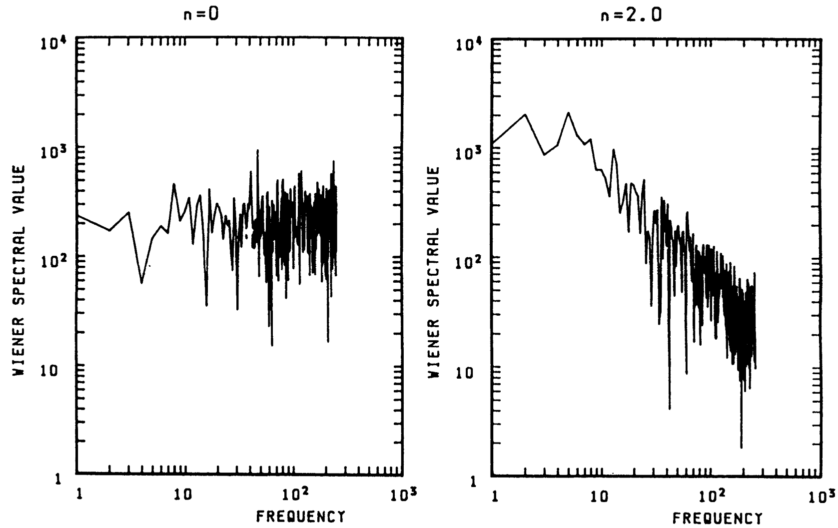

Fig.11 Wiener spectra of $1/f^n$ noise

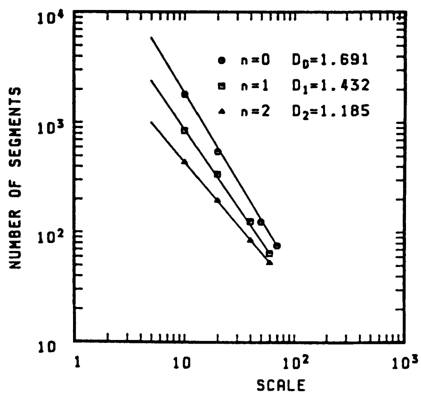

Fig.12 Fractal dimension of $1/f^n$ noise

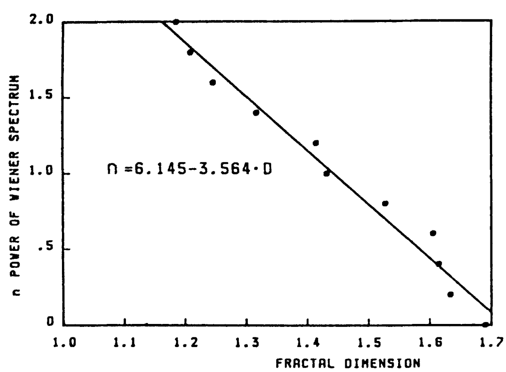

Fig.13 Relationship of fractal dimension D and exponent n of $1/f^n$ noise

CONCLUSION

Fluctuation of film density obtained from screen-film system has the property of fractality,the dimension of which has a close relation with Wiener spectrum,and can be used to evaluate graininess of X-ray film.

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Q: Why did you use D/A converter for computing fractal dimensions? Did you construct some special instrument? I would like to know why you didn't use computer programming to compute them? (N. Funakubo)

A: For the purpose of displaying the fluctuating curves, we used a D/A converter.