Introduction

In a previous paper, we examined the requirements for a high quality image recording medium and presented a new high resolution hardcopy system. The essential part of this imaging system is a film that is composed of a laser sensitive layer and an image forming layer. Imaging is performed using high power solid state lasers, and images are developed without chemical processing. The imaging mechanism of the new system is quite binary. Upon exposure, a high definition spot of maximum optical density, equal to 3.5, is produced. This process is digital and highly deterministic. Spots as small as 2 \( \mu \text{m}^2 \) can be achieved under proper exposing conditions.

Construction of Tonescale

Since each spot forms a tiny black area, a continuous tonescale must be created using area modulation. In general, imaging systems based on area modulation techniques fail to produce high quality continuous tone images.

One difficulty arises as the area of the exposed portion of a pixel \( A_n \), is increased to form optical densities from \( D_{\min} \) to \( D_{\max} \). Light transmissivity, \( T_n \), is a linear function of the exposed area,

\[
T_n = \left( \frac{A_n}{A} \right) T_{\max} + \left( 1 - \frac{A_n}{A} \right) T_{\min},
\]

(1)

where \( A \) is the total pixel area, \( T_{\max} \) and \( T_{\min} \) are the maximum and minimum light transmission values. However, the optical density, \( D_n = -\log T_n \propto \log A_n \), is a logarithmic function of the written pixel area. Therefore, at high optical densities, the size of the necessary areal increments decreases exponentially, see figure 1. To create all the required densities, very small areas must be precisely modulated and positioned accurately. This places great demands on the film performance as well as the positioning hardware.

![Figure 1](image)

OD= 0.3 OD= 0.6 OD= 0.9

OD= 1.2 OD= 1.5 OD= 1.8

Figure 1. Exposure area is increased as higher optical densities are sought and the demand for area increases exponentially.

The choice of large pixel area can facilitate achieving small increments in density in the high density areas, since it relaxes the constraint on the written area increment required. However, there is a tradeoff between pixel size and pixel visibility that demands that the system be able to address very small areas. A second difficulty with area modulation is encountered if the contiguous written pel area is large. Pel visibility creates texture which can result in an ordered noise in the image. A third difficulty with area
modulation occurs if the incrementally addressable pel area exceeds the contrast visibility threshold at the particular density being written. In this case artificial contours can result in image areas of slowly varying density. A fourth difficulty is depicted by considering the density produced when the first single pel is written. For imaging applications demanding a high dynamic range of densities, the smallest first pel size written becomes the limiting factor.

In summary, image quality for systems utilizing area modulation is limited by the size of the pixel (spatial resolution), the incremental area written (density resolution), the size of the contiguous pel written (texture), and the smallest first pel written (dynamic range). In order to improve apparent image quality utilizing output devices exhibiting limited capabilities, researchers working in digital imaging have developed innovative imaging techniques such as dithering, threshold arrays, and introducing different types of noise. However, these methods did not eliminate the problems described above or improve the dynamic range of the devices, and occasionally even created new artifacts. The basic limitations continued to be the stochastic nature of the recording medium and the lack of ability to reliability produce pels smaller than 20μm².

New Method for the Construction of Continuous Tonescale

For the imaging system we developed, it is not necessary to use dither or noise techniques to create a continuous tonescale. To optimize system design, we performed psychophysical studies to estimate the ideal size of a pixel and pel with regard to visibility and texture. Experiments and calculations as well as engineering considerations were used to determine the pixel and pixel element (pel) sizes with regard to density dynamic range. The result of this work led to the construction of a paint brush illustrated in figure 2, which consists of two different pel sizes. Optical densities are created using a modified pulse surface area modulation (MPSAM) technique, with completely deterministic pel positioning functions. These functions are optimized for the film properties, such as pel edge quality and peeling performance.

\[
A_n = \sum_{i=0}^{n} (a_0 + i\Delta a) .
\] (2)

Moreover, \(A_0\) and \(\Delta A\) can be written in terms of \(a_0\) and \(\Delta a\),

\[
A_0 = a_0 + k\Delta a ,
\] (3)

and

\[
\Delta A = m\Delta a
\] (4)

This method quantizes the pixel area \(A\) to a large number of small areas \(\Delta a\), providing fine resolution in optical density.

Figure 3 shows schematically these two ways of modulating the pixel area. This high degree of flexibility in modulating the pixel area allows the creation of very high quality tonescales, and the construction of practically any tonescale curve shape between a \(D_{\text{max}} = 2.85\) and \(D_{\text{min}} = 0.01\).
With novel imaging algorithms\(^6\) we generate 8 to 10 bits of discernible shades of gray.

The MTF of the system is independent of the optical density, and does not change with decreasing the line spacing up to the size of the pixel. We used a pattern of bi-directional lines of varying spacing to measure the MTF, and compared that with results obtained by printing the same pattern on a high quality laser imager. The results are shown in figure 4, where we magnified the printed images by a factor of 50.

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REFERENCES


