

TWO-DIMENSIONAL DIGITAL HALFTONING BASED ON WEIGHTED LEAST-SQUARES FOR LASER CARVING GRAVURE CYLINDER TECHNOLOGY AND DETECTING SYSTEM OF INK CELLS VIA NEURAL NETWORK

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ABSTRACT

Laser carving technology has the advantages of higher resolution, focusing precision and digital modulation. It has been widely used in laser engraving gravure plate and laser plate processing. However, the switching of the laser has only two states, so the halftoning processing plays a very important role in the laser plate. In this paper, we present a 2-dimensional digital halftoning method based on weighted least-squares (WLS) which can significantly gain high quality image during the processing of laser plate. Two main strategies were made. The first is adding a procedure to partition into several finite regions using K-means image segmentation and least squares to reduce the total quantizing error. The second is that the statistics of the mean and variance of the gray-scale pixel of each clustering are calculated and the new energy function is constructed using the weighted least squares method, which the reciprocal of the variance of the segmented regions are referred to as the weighting operator. The analysis and simulation results show that the proposed algorithm produces better gray-scale halftone image quality when we increase the number of clustering with a certain range. A performance measure for halftone image is used to evaluate our method. We apply neural network to build up a detecting system of ink cells in gravure cylinder. We use different thresholds and experimental sigma values that compare to experimental results. Binarization images are obtained through adaptive threshold segmentation, which regards the value of gaps and dark tone as the characteristic value when they start to detecting. We extract size and surface defects of ink cells for grading. The areas of ink cells are deemed to size characteristics. Then we classify the ink cells into two classes by using of neural network. The experimental results consider neural network model that produce consequences.

Keywords: *Laser Carving Technology, Digital Halftoning, Weighted Least Squares, Ink Cells in Gravure Cylinder, Neural Network, Value of Gaps and Dark Tone*

1. INTRODUCTION

Laser carving technology is an applied technique developed in the 1980's. But its application range has widely expanded combined with CAD, computer graphic, industrial automation, information technology etc. Laser carving system for digital image is one of laser carving applications, which derived from computer integrated numerical control system based on digital image processing. Without loss of generality, the surface of the plate has been efficiently carved into a number of square area, which the surface regions

have a high spatial resolution during the process of plate. Laser carving technology has the advantages of higher resolution, focusing precision and digital modulation. It has been widely used in laser engraving gravure plate and laser plate processing.

As shown in Figure1, rotary gravure plate consists of a uniform galvanized copper roller. The image information is carved into the tiny ink cells galvanized and the ink is transferred to the substrates using a pulsed laser beam.

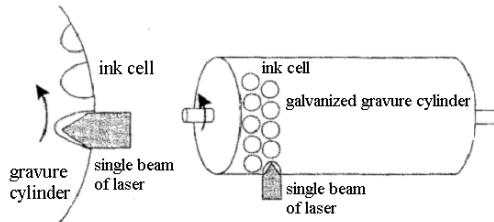


Figure 1 : Laser Carving the Galvanized

The traditional ink cell (the depth variational and diameter invariable on the gray-scale) can be generated by the flat waveform. Half-auto-typical ink cell (the depth and diameter can be change on the gray-scale) can be generated by a Gaussian laser beam waveform. It is shown in Figure 2. Ink cell size rely on the pulse energy.

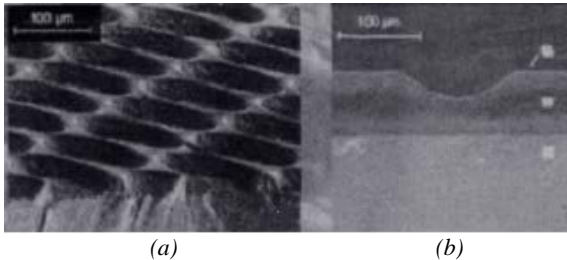


Figure 2 : The Shape of Ink Cell (a) Traditional Ink Cell (b) Half-auto-typical Ink Cell

In this paper, we present a 2-dimensional digital halftoning method for the laser carving processing. Halftoning is a method for creating the illusion of continuous tone output with a binary device. Effective digital halftoning can substantially improve the quality of rendered images at minimal cost[1]. The halftoning algorithms can be broadly classified into three categories[2]. These include ordered dithering, error diffusion and optimization-based techniques. The goal of model-based halftoning techniques is to exploit explicit models of the display device and the human visual system (HVS) to maximize the quality of the displayed images[3].

Many practical but suboptimal search techniques have been proposed to perform the minimization procedure. They include a dual interpretation direct binary search[4], one-dimensional Viterbi algorithm[5], blocking with greedy bit flipping[6], blocking with branch and bound minimization[7], diffusion-reaction model[8]. The Lsmb halftoning approach attempts to produce an optimal halftoned reproduction. The error criterion of the Lsmb approach provides a measure of halftone image quality that takes into account the characteristics of both the display device (printer) and the human

visual system and can be used to evaluate the performance of any halftoning technique[9].

The rest of the paper is organized as follows. In section 2, we present the gray image that is partitioned into several finite regions using k-means image segmentation method. The statistics of the mean and variance of each clustering is calculated. The building of halftoning error metric is presented in section 3. In section 4, we build the energy function, which to minimize error metric by Direct Binary Search method. Section 5 discusses the results and presents examples of the halftone quality results that can be achieved. Section 6 build the detection system of ink cells via neural network. Section 7 is a brief conclusion with comments on future work.

2. SEGMENTATION USING CLUSTERING METHOD

An algorithm for partitioning (or clustering) N data points into K disjoint subsets S_j containing N_j data points so as to minimize the sum-of-squares criterion.

$$J = \sum_{j=1}^K \sum_{n \in S_j} |x_n - \mu_j|^2 \quad (1)$$

where x_n is a vector representing the n th data point and μ_j is the geometric centroid of the data points in S_j . In general, the algorithm does not achieve a global minimum of J over the assignments. In fact, since the algorithm uses discrete assignment rather than a set of continuous parameters, the “minimum” it reaches cannot even be properly called a local minimum[10].

The algorithm consists of a simple re-estimation procedure as follows[11]. Initially, the data points are assigned at random to the K sets. For step 1, the centroid is computed for each set. In step 2, every point is assigned to the cluster whose centroid is closest to that point. The processing of K-means clustering is shown in Figure 3.

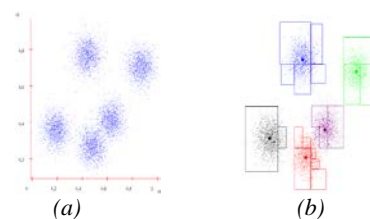


Figure 3 : The Iterative Processing of K-means Clustering (a) Step 1 (b) Step 2



3. HALFTONING ERROR FIELD AND WEIGHTED LEAST-SQUARES

In this section, the relationship between the Human vision system(HVS)/printer model and the halftoning algorithm have been set up[12].

Let $f [m,n]$ be the continuous-tone image and $f (x,y)$ be the rendition of this continuous-tone image by an ideal printer. Let $g[m,n] = 0$ or 1 represent the halftone image. Then, the following equations hold:

$$f(x, y) = \sum_{m,n} f[m,n]p(x - mX, y - nY)$$

$$g(x, y) = \sum_{m,n} g[m,n]p(x - mX, y - nY)$$

$$p(x, y) = \text{rect}(x / X, y / Y)$$

where $p(x,y)$ is the dot rendering function of an ideal printer, and X and Y are the basis for the lattice of printer addressable dots in units of in/dot.

A HVS model is a linear shift invariant filter based on the Point Spread Function (PSF) of the human eye, which will be denoted by $h(x,y)$. The perceived continuous-tone image is given by

$$\square f(x, y) = f(x, y) ** h(x, y) = \sum_{m,n} \square f[m,n] p(x - mX, y - nY)$$

where $**$ denotes 2-D convolution and $\square p(x, y) = p(x, y) ** h(x, y)$ embodies the effects of cascading the printer rendering and HVS model. Similarly, the perceived halftone image can be written as

$$\square g(x, y) = \sum_{m,n} \square g[m,n] p(x - mX, y - nY)$$

then, the perceived error between the continuous-tone image and the halftone image is given by

$$\square e(x, y) = \square g(x, y) - \square f(x, y)$$

The goal of least-squares halftoning is to find the optimal halftone image which minimizes the total squared error.

$$E_{x,y} = \sum_{x,y} (g_{x,y} - f_{x,y})^2$$

Weighted least squares (WLS) regression is useful for estimating the values of model parameters when the response values have differing degrees of variability over the combinations of the predictor values[9].

Optimal results that minimize the uncertainty in the parameter estimators are obtained when the

weights used to estimate the values of the unknown parameters are inversely proportional to the variances at each combination of predictor variable

$$\text{values } \lambda_i \propto \frac{1}{\sigma_i^2}$$

In the proposed approach, we seek the halftone image that minimizes the weighted squared error

$$E_{x,y} = \sum_{k=1}^4 \lambda_k \sum_{x,y} (g_{x,y} - f_{x,y})^2 \tag{2}$$

The λ_k ($k=1,2,3,4$) are weighting operators and $*$ indicates convolution. Note that we have allowed different impulse responses for the eye filters corresponding to the halftone and continuous-tone images.

4. DIRECT BINARY SEARCH (DBS) AND ERROR METRIC

The goal of DBS is to determine the binary halftone image $g[m,n]$ such that the difference between the perceived versions of the original gray-scale image and the rendered halftone is minimized. As a measure of the difference, the total squared error is equation [13].

We model the low pass characteristic of the eye with a luminance spatial frequency response function (model by Mannos and Sakrison[8]).

$$H_r(f_r) = 2.6(0.0192 + 0.114f_r) \exp\{-(0.114f_r)^{1.1}\} \tag{3}$$

f_r in Eq. (3) is the spatial frequency of the visual stimuli given in cycles/degree. The function has a peak of value 1 approximately at $f_r = 7.9$ cycles/degree, and is meaningless for frequencies above 60 cycles/degree.

We compute this error efficiently by computing first the autocorrelation function of the filter, C_{pp} and the correlation between the error and the filter, C_{ep} . This is acceptable though, because especially in the last passes over the image, we try much more changes than the number we accept.

$$C_{pp}[m, n] = C_{pp}(mX, nY) \quad C_{ep}[m, n] = e[m, n] * C_{pp}(m, n)$$

In DBS, there are two kinds of pixel changes, toggles and swaps.

5. HALFTONING EXPERIMENTAL RESULTS AND DISCUSSIONS

In this paper, we use the Bridge image of sizes 512×512 to demonstrate the experimental results.

All halftones are generated and printed at a resolution of 300dpi and 24inches viewing distance. In the experiment, we compare two algorithms: Lsmb, and proposed algorithms.

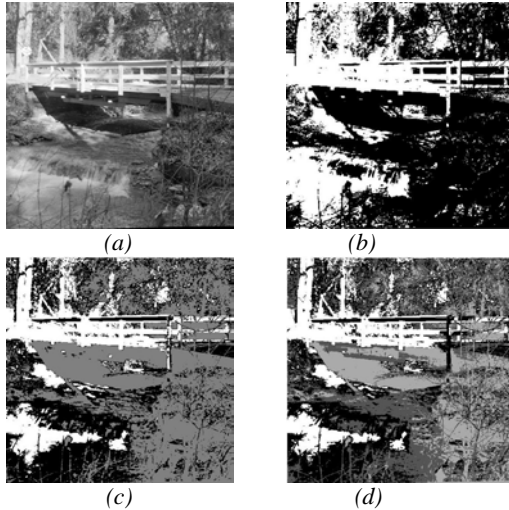


Figure 4: Original Image and Image Labels by Cluster Index K (a)Original Image(b)K=2(c)K=3(d)K=4

Seen from Figure 4, there are two, three and four regions generated by the clustering. The statistics of the mean and variance of the gray-scale pixel of each clustering are calculated. The results are shown in Table 1.

Table 1: Pixels statistics for each cluster

Clustering	μ	σ^2
2 K= I	81	776
K= II	173	1124
3 K= I	64	433
K= II	125	376
K= III	199	612
4 K= I	52	274
K= II	98	187
K= III	147	229
K= IV	208	260

Then we use the proposed algorithm to obtain the halftone images.

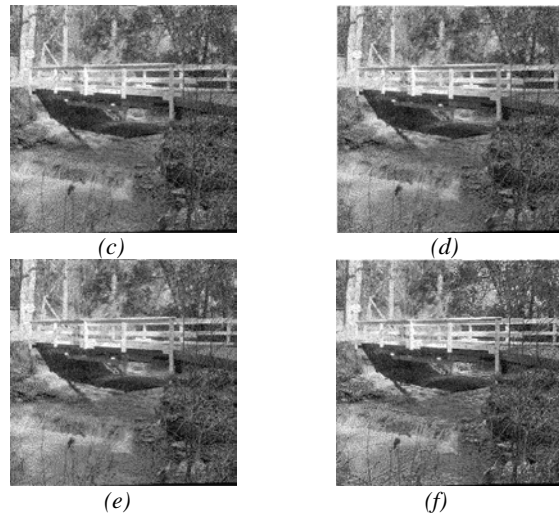


Figure 5: Bridge Halftoning using Lsmb and Proposed Algorithm (a)Original Image (b)Initial Halftoning Image (c)Lsmb Algorithm (d) Proposed Algorithm in K=2 Weighed Operator λ_1, λ_2 (e)Proposed Algorithm in K=2 Weighed Operator λ_1, λ_2 and λ_3 (f)Proposed Algorithm in K=2 Weighed Operator $\lambda_1, \lambda_2, \lambda_3$ and λ_4

The Figure 5 (c)(d)(e)(f) show the halftone of Bridge generated with the proposed algorithm for the cluster classes K=2,3 and 4 and the weighted $\lambda_1, \lambda_2, \lambda_3$ and λ_4 . On testing images, we founded that when comparing the quality measurements of halftone images with MSEv and PSNR. We plot the MSEv and PSNR for the test image in Figure 6 and Figure 7.

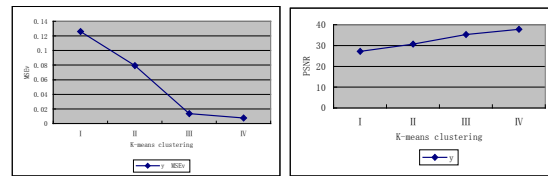


Figure 6: Comparison of the Value of MSEv

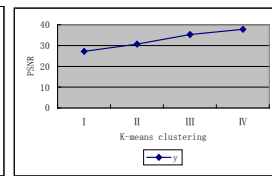


Figure 7: Comparison of the Value of PSNR

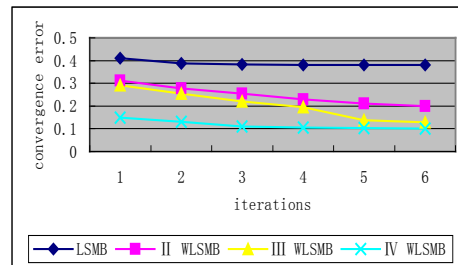


Figure 8: Comparison of the Number Iterations for The Test Image

It is clear from Figure 6 that the proposed algorithm achieves consistently lower values of MSEv than the Lsmb algorithm, and with the

increase in cluster partition, the value of MSE_v is also decreases. We can be seen from Figure 7 that the proposed algorithm achieves consistently higher values of PSNR than the Lsmb algorithm, and with the increase in cluster partition, the value of PSNR are also increase. During the running of the program, the Lsmb algorithm iterates six times, while the proposed algorithm iterates four times, the convergence error down to 0.25. Figure 8 shows that the proposed algorithm can further reduce the number of iterations.

6. DETECTING SYSTEM OF INK CELLS VIA NEURAL NETWORK

The gray-scale image quality of laser carving gravure cylinder depend largely on the quality of ink cells of the gravure cylinder. But at present, the vast majority of gravure manufacturing enterprises produced good gravure test sample cells by use of artificial or semi-automatic method[14]. Machine vision inspection system is mainly used in the quality of printed matter rather than printing plates.

In abroad, studied on offset and gravure on the automatic detection system by Rafail Bronstein, Omer Karp, and Goldstein has been advanced by the United States Scitex Vision Technology Co. Ltd and proxy, which applied for the patent[15]. Based on machine vision detecting technology is mainly used in quality inspection of agricultural products[16]. Since 2000, the machine vision technology has also been applied to sorting timber, ore, chemicals and other products classification.

We apply neural network to build up a detecting system of ink cells in gravure cylinder. The experimental results consider neural network model that produce properly sorting and gain true systematization consequences.

A computer-aided ink cells quality assessment and detecting system has two subsystems: a computer vision system and a ink cells handling system[17]. Figure 9 show computer-aided sorting system processes.

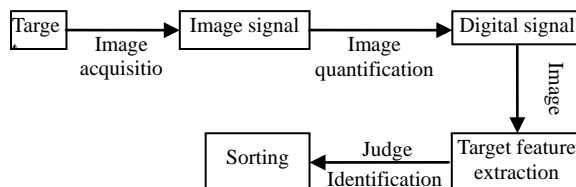


Figure 9: Computer-aided Sorting System Processes

In the process of laser engraving of the ink cells, each ink cell is formed that the graver is completed a movement rather than time after time engrave.

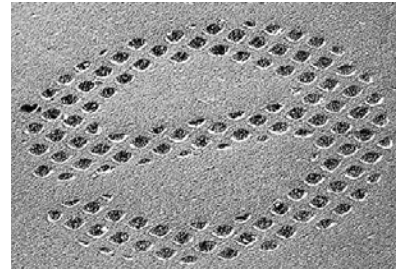


Figure 10: The Ink Cells of Gravure

The ink cell information is shown the Figure11[18]. When T and sigma are the default value, the edge of Figure11(c) is extracted by use of Canny operator[19], Binarization images are obtained through adaptive threshold segmentation.

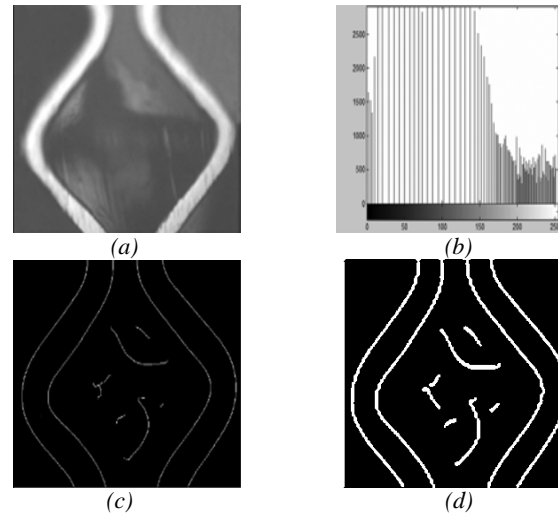


Figure11: Read the Results of Information Cell(a)Original Image (b)The Histogram of Equalization(c)Canny Operator Extraction Sigma=16 (d) Binarization Images $t = 0.10$

In this paper, we chose the threshold equal to 0.10. The value of gaps and dark tone are the image feature value. The bright is 1, the other part is 0 in the detected edge image. By the detected edge image analysis shows that the value of dark tone corresponds to the image matrix of horizontal distance of two points. At first, there are highlights the location coordinates in the edge image, it is i and j , the jm is the largest horizontal coordinates, the js is the smallest horizontal coordinates. Hypothesis s is the value of dark tone and s is the difference with the js and jm . In addition to using the progressive test, the calculation of value of the gaps is the same as the dark tone. On the edge of the image all the columns of matrix of the first transverse are scanned that the results are no bright spots, then the second line are scanned, the value of r and c are get.

According to the image used in this research to determine the standard cells carving gaps value of d_0 equal 125, the value of dark tone s_0 equal 394, so the standard range of are $d_0 \pm 10$ and $s_0 \pm 10$. The value of gravure outlets gaps and dark tone are measured, while d and s is in the scope of standard range, which the output 1 of the cells determined to pass and the output 0 deemed to have failed. The first piece of the original image runs the program which the result of z is 1, it is qualified. In this article, four experimental original manuscripts run all programs which the results show in Table 2.

Table 2: The Test Data of Four Experimental Original Images

Name	Original Manuscript			
	1	2	3	4
jm	421	418	429	431
js	19	20	26	27
s	402	398	403	405
r	1,1,1,1	1,1,1,1	1,1,1,1	1,1,1,1
c	143,189, 235,280	142,189, 238,289	139,189, 245,291	138,190, 246,290
cm	280	285	291	290
cs	143	142	139	140
d	137	143	152	153
z	1 Qualified	0 Un-qualified	0 Un-qualified	0 Un-qualified

The experimental results of the second, third and fourth piece of the original images show in Figure 12. Segmentation pictures are extracted by K-means clustering. The areas of ink cells are deemed to size characteristics. The results of segmentation is shown in Figure 13.

American computer scientist F. Roseblatt was proposed perceptron convergence theorem in 1957[20].

$$n_i = \sum_{j=1}^r w_{ij} p_j, \quad a_i = f(n_i + b_i)$$

where, n_i is the i 'th weighted neuron total inputs. a_i is the i 'th neuron output, $i=1,2,\dots,s$.

The basic function of the perceptron that the input vector is converted to the output vector which it is 0 or 1. According to test the total weighted output value is located in left and right of the threshold function which to classify the input data.

$$a_i = \begin{cases} 1 & n_i + b_i \geq 0 \\ 0 & n_i + b_i < 0 \end{cases}$$

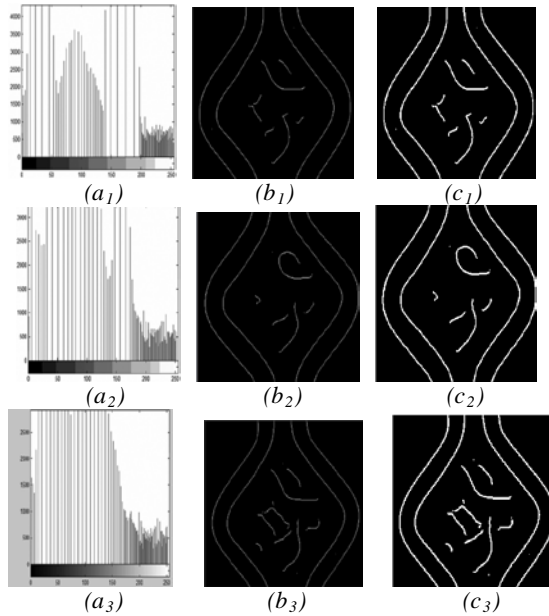


Figure 12: The Results of Experiments Original Manuscript 2,3 and 4 ((a)Histogram of Equalization (b)Edge Extraction (c) Binarization



Figure 13: The results of Segmentation

This function can be explained by mapping the input vector space. For example, the input vector $r=2$, for the selected weight w_1, w_2 and b , we are regard P_1 and P_2 as horizontal and vertical axis, respectively, which to draw the geometric locus of $w * p + b = w_1 * p_1 + w_2 * p_2 + b = 0$ that is a straight line when $w_1 * p_1 + w_2 * p_2 + b > 0$, the value of P_1 and P_2 locate the straight line and above, the output of perception is 1, else 0.

When we apply the perceptron to classification for different input vectors for the desired output 0 or 1, the problem can be transformed the input vector into in the input space formed by different points of location to design perceptron weights w and b . The purpose of perceptron weight parameter is design a path of $w * p + b = 0$ according to learning law which to achieve the desired division for the input vectors.

We are calculated the new weight matrix W and bias B of a new algorithms. Changing the amount of

weight equals to the input vector. Assume that the input vector P , the output vector A , the target vector T .

$$\Delta w_{ij} = (t_i - y_i) \times p_j$$

$$\Delta b_i = (t_i - y_i) \times 1$$

In this article, determine the input vector P , the target vector T , and determine the vector dimension and number of neurons: r , s and q . Parameter initialization a) Assign the weight vector w in $(-1,1)$ random non-zero initial value. b) Give the maximum training cycle max-epoch.

Firstly, we classify the cells in gravure cylinder according to the characteristic, namely, given the value of perceptron input vector P and the target output vector T . Figure 14 can be seen to determine the location of the border.

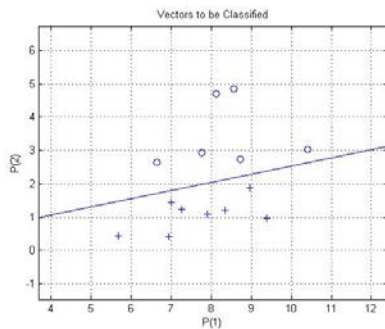


Figure 14: Perceptron Training

We use the trained perceptron to classify samples of unknown type. We are trained to detect 14 samples of gravure cells, and use the perceptron test four new samples. The results show in Figure 15.

The simulation results show that gravure cells have been successfully sorted using perceptron neural network. This shows the validity of proposed method.

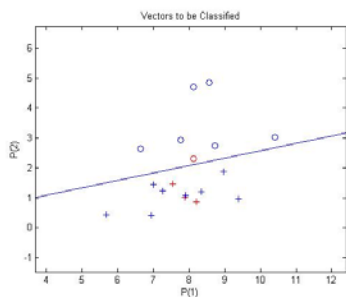


Figure 15: Application of Perceptron

7. CONCLUSIONS

This paper developed a based on the weighted least squares digital halftoning. A detailed analysis

on the proposed algorithm was presented. Analysis results show that the proposed algorithm produces better gray-scale halftone image quality when we increase the number of clustering, in particular details of the image. Simulation results also demonstrated that the proposed algorithm achieves consistently lower values of MSEv than the Lsmb algorithm. As the cluster partition increases, the value of MSEv decreases. And the proposed algorithm achieves consistently higher values of PSNR than the Lsmb algorithm. As the cluster partition increases, the value of PSNR decreases. The proposed algorithm can further reduce the number of iterations. The main contents of cells in gravure cylinder are extract image feature value and sorting. We regard the machine vision as the theoretical basis for establishing the sorting system of cells in gravure cylinder. Firstly, the cells images are gained in the images capturing device. We have applied the MATLAB to read the experiment images and histogram equalization. The edge of cells is extracted by using of Canny operator. The value of gravure outlets gaps and dark tone are measured. Binarization images are obtained through adaptive threshold segmentation, which regards the value of gaps and dark tone as the characteristic value when they start to sorting. Then we apply neural network to classify the cells to two classes. The experimental results consider neural network model that produce properly sorting and gain true systematization consequences.

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