A Method to Enhance Images Based on Human Vision Property

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Abstract—**Image information for target detection and recogniton is determined by grayscale value relationship between pixels.The human eye is unable to perceive too small nonzone grayscale value difference.Therefore human eyes may not always perceive the whole image information for target detecting and recognizing. To enhance image information for human detecting and recognizing targets, a method is proposed in this paper to nonlinearly map the grayscale values of pixels in the orignal image to the new grayscale values of pixels in the enhanced image guided by human vision property.**

Keywords-Human Vision Property; Grayscale Value Difference; Perception Degree

I. INTRODUCTION

Digital images are an important information carrier, one usage of which is watched by human eyes. So it is important in engineering application to enhance images according to human vision property. Image information for target detection and recognition is not determined by grayscale values of pixels but the grayscale value relationship between pixels. The grayscale value relationship of one pixel with the value of another pixel could be that the grayscale value of the pixel is bigger than the grayscale value of another pixel， smaller than another or equal to another. The image information is not changed as the grayscale value relationship between pixels is kept but the grayscale values of pixels are changed. As showed in Fig. 1, the grayscale values of pixels among the three images are different, but the same circle has been seen by human eyes. The relationship between pixels can be classified into neighbouring and non-neighbouring. The grayscale value relationship of neighbouring and non-neighbouring pixels both are needed for human to correctly detect and recognize targets, though the importance is different. Human eyes would perceive identical pixel grayscale values when the difference between the grayscale values of pixels is nonzero but too small. Then human cannot always perceive the whole image information for target detecting and recognizing. It is concluded from research achievements of human vision property that human eyes are harder to detect grayscale value difference between pixels as the difference between pixels become smaller. It would enhance image information for human eyes detecting and recognizing targets to increase the grayscale value difference between pixels. Image enhancement is a process to enhance the needed image information for human. The enhancement methods, such as contrast linear stretching[1], gamma correct-

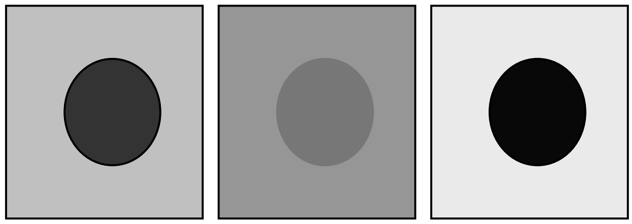

Figure 1. An example about image information keeping.

tion[2], histogram equalization[3], retinex[4] stretch the contrast of the image to enhance images. Most image enhancement methods would not guarantee keeping the grayscale value relationship of pixels. So it is possible that the image information for target detection and recognition has been damaged in the enhanced image.

Contrast linear stretching and gamma correction enhance the image with keeping the relationship of grayscale values of pixels. Contrast linear stretching linearly stretches dynamic range of the image pixel grayscale value to the whole grayscale space. Gamma correction method exponentially stretches the dynamic range. Contrast linear stretching and gamma correction both not employ human vision property in enhancing images.

Image enhancement needs to map the grayscale values of pixels in the original image to new grayscale values in the enhanced image. Designing an enhancement method is to design a mapping function to process images in essence. Keeping grayscale value relationship between pixels demands that the grayscale values of pixels of which the grayscale values are identical in the original image is identical in the enhanced image. So finding the mapping function for each pixel's grayscale value is equivalent to finding the mapping function for each gray level. Although the human eye perception degree of any couple pixels of which the grayscale value difference is nonzero is smaller when the distance between the couple is bigger, the perception degree of grayscale value difference between neighboring pixels is set as the perception degree of grayscale value difference between the corresponding gray levels. It is proposed to enhance image information for human eyes detecting and recognizing targets in this paper that maximizing the minimum perception degree of grayscale value difference of gray levels which the grayscale value of at least one pixel is equal to.

The paper is organized as follows: In section I, image enhancement for human detecting and recognizing targets is briefly described. Then in section II, the background

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knowledge about human vision property is introduced. Section III will describe the enhancement method proposed. Experiment results of image enhancement are showed in Section IV. Section V gives some concluding remarks.

II. BACKGROUND KNOWLEDGE

In the last hundred years, human vision property has been researched thoroughly. Although widely accepted precise human eye imaging model has not appeared, some important research achievements can be employed to assist image enhancement. The followed equation is the human eye perception function founded by Foly and Legge from statistics of trails [5,6]（showed in Fig. 2）.

$$p(s)=\frac{1}{\sigma\sqrt{2\pi}}\int_{-\infty}^{s}e^{-\frac{(x-s_0)^2}{2\sigma^2}}dx \tag{1}$$

The human eye perception function can calculate out the probability that human eyes have detected that grayscale values difference between the background grayscale value and the grayscale value of the target. In the function, s_0 equals to the grayscale value difference when the probability that human eyes have detected the grayscale difference is 50%. σ is a constant, and the value of s_0/σ is about 2.3~4.

Just Noticeable Difference (JND) is the minimum difference of signal strength when the difference is noticed by human. At 1995, Chun-Hsien Chou etc. draw a JND curve which is measured through recording the noticed minimum grayscale value difference between the target and the background(as showed in Fig. 3) [7]. In Fig. 3, the x-axis denotes background grayscale value, while y-axis denotes the noticed minimum grayscale value difference. The curve tells out that the perception degree of human eyes in the grayscale space is not uniform. The JND values is corresponding to the s_0 in the human perception function. The human perception function and the JND curve have formed an imperfect but compact model of human vision property. This model can be applied in image enhancement contributing for human detecting and recognizing targets.

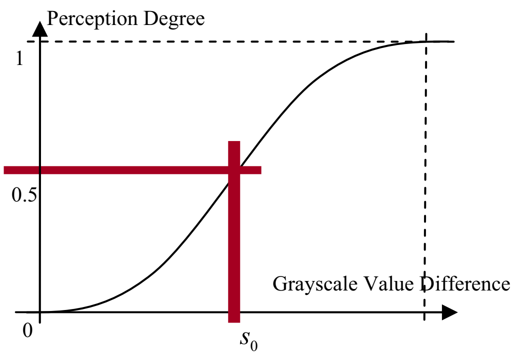

Figure 2. Human Eye Perception Function

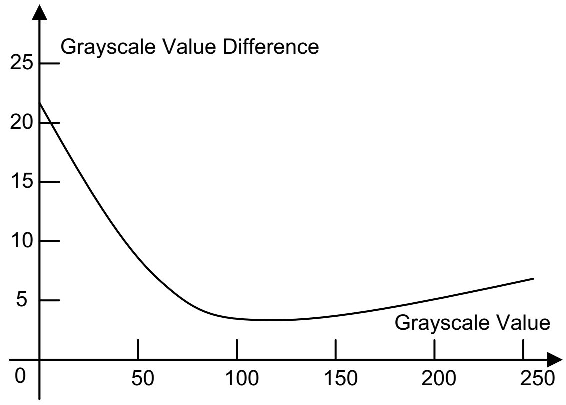

Figure 3. JND Curve

III. ALGORITHM

It is pointed out here that the grayscale value dynamic range of images processed in this paper is 0-255. In the histogram of an image, the gray levels which the grayscale value of at least one pixel is equal to is labelled and added into the sequence l. The number of gray levels in l is denoted by M .After Ascending sort, it turns out $l=\{g_1,g_2,...,g_M\}$. The mapping function which maps gray levels in the original image to gray levels in the enhanced image is:

$$G_i=f(g_i) \tag{2}$$

In the enhanced image, the corresponding gray levels make up a new sequence $L=\{G_1,G_2,...,G_M\}$ after mapping. Keeping the grayscale value relationship between pixels can be denoted by:

$$(G_i-G_j)\times(g_i-g_j)>0 \tag{3}$$

The target of the enhancement method proposed in this paper is maximizing minimum human eye perception degree for grayscale value difference between gray levels which are in L. It is easy to know but not proved in this paper that the minimum perception of grayscale value difference between gray levels which is in L is maximized when the perception degree of grayscale value difference between any couple of gray levels which are neighbored in L is identical.

A perception approximate-evenly distributed virtual grayscale space is designed in this paper. In this virtual space just the JND values of every grayscale value is demanded to be identical. When the image is mapped from the normal gray space (NGS) to the perception approximate-evenly distributed virtual grayscale space (PEDVS), the perception degree of grayscale value difference in PEDVS is regarded as the same no matter what the grayscale value is. Evenly distributing the elements of L in PEDVS will lead to the same perception degree between any couple of gray levels which are neighbored in L . The JND Curve in PEDVS is showed in Fig. 4.

A. *Designing perception evenly distributed virtual grayscale space*

In PEDVS, the JND value is a constant denoted by k.
Function $T(x)$ is the mapping function between NGS and

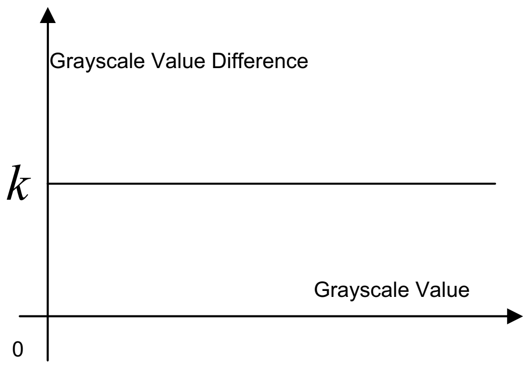

Figure 4. The JND Curve in PEDVS

PEDVS. In NGS, if the JND value of gray level i is $j-i$, then $T(j)-T(i)=k$. Function $T(x)$ is subjected to (4).

$$\begin{cases} T(0+J(0))-T(0)=k \\ T(1+J(1))-T(1)=k \\ T(2+J(2))-T(2)=k \\ \vdots \\ T(n+J(n))-T(n)=k \end{cases} \quad (4)$$

s.t. $\quad 0 \le n \le 249$

In (4) $J(x)$ returns the JND values of grayscale levels in NGS. This equation group is linear. There are 257 variables with 250 equations in the equation group. The solution for the equation group is a 7D space. Other constraints which are depicted in (5) are added to get a specified solution.

$$\begin{cases} T(0)=0 \\ k=144 \\ T(162)=[T(164)-T(161)]/3+T(161) \\ \text{T}(203)=[\text{T}(205)-\text{T}(202)]/3+\text{T}(202) \\ \text{T}(244)=[\text{T}(246)-\text{T}(243)]/3+\text{T}(243) \\ T(158)-T(157)=k/3 \\ T(157)-T(156)=k/3 \end{cases} \quad (5)$$

There are gray levels which are denoted by i in NGS meeting $J(i)=J(i+1)+1$. Then:

$$\begin{cases} T(i+J(i))-T(i)=k \\ T(i+1+J(i+1))-T(i+1)=T(i+J(i))-T(i+1)=k \end{cases} \quad (6)$$

It is reasoned out from (6) that $T(i)=T(i+1)$, which is irrational. The irrational gray level mapping relationship is caused by JND Discretization error. So (6) is rationally modified to be:

$$\begin{cases} 0.5T(i+J(i))+0.5T(i+J(i+1))-T(i)=k \\ T(i+1+J(i+1))-T(i+1)=k \end{cases} \quad (7)$$

Now just a specified solution is left for PEDVS. The space mapping function is showed in appendix table 2. The maximum gray level in PEDVS is denoted by P.

B. Gray level mapping function

$V=\{t_1,\cdots,t_{M-1},t_M\}$ is a gray level sequence in PEDVS. If the elements of V are distributed evenly in PEDVS, the perception degree between neighbored gray levels in V is uniform. Then $t_i=(i-1)P/(M-1)$. According to $G_i=T^{-1}(t_i)$, the gray level mapping function is calculated out:

$$f(g_i)=T^{-1}((i-1)\frac{P}{M-1}) \quad (8)$$

The value of variable x in function $T^{-1}(x)$ must be picked out from appendix table I. In our method t_i is rounded down. The rounding error is not discussed in this paper. But when $M>174$:

$$\exists j \in [0,M] \quad T^{-1}(t_j)=i, T^{-1}(t_{j+1})=i \quad (9)$$

According to (9) the relationship of grayscale value between pixels after enhancement will be changed. It is needed to record the NGS gray levels set Q which are subjected to $T(i+1)-T(i)>P/(M-1)$. The number of elements in Q is recorded as N. In PEDVS N gray zones whose length is $Len=\sum_{i\in Q}T(i+1)-T(i)$ are occupied by the elements in Q. If no gray level i in NGS excluding gray levels in Q meets:

$$T(i+1)-T(i)>(P-N\times Len)/(M-N) \quad (10)$$

The left gray level space of PEDVS will be equally partitioned by $M-N$ gray levels, otherwise the front steps need to be repeated to keep the relationship of grayscale value between pixels. Now the mapping function is determined. The enhanced image is out by mapping the grayscale value of pixels in the original image to the new grayscale value of pixels in the enhanced image.

IV. Experiments and Results

The proposed method is compared with contrast linear stretching and gamma correction in enhancing plenty of images. In this experiment, the gray level mapping function of gamma correction is $g(u)=(u/255)^{r+1}$. The value of r has been set as 0.6, 0.7, 0.8, 0.9 and 1.3 respectively. In this paper, only the gamma correction enhancement images with r equaling 0.7 which enhanced the image better than other values of r are showed. The images are showed in Fig. 5. It is revealed that the images enhanced by the proposed method are more comfortable than the other two methods for human eyes.

V. Conclusion

In this paper, it is pointed out that the image information for human detecting and recognizing targets is determined by the relationship of grayscale values of pixels. Subjecting to keeping the relationship of grayscale values of pixels, we enhance the image by maximizing the perception degree of gray levels which the grayscale value of at least one pixel equals to. The enhancement is processed quickly with a good performance for assisting human detecting and recognizing targets.

Original image The proposed methodContrast linear stretching Gamma correction

Figure 5. Image enhancement comparison

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Appendix

The PEDVS mapping function is showed in appendix table I. The input and output values both are one dimension array, while the output values are printed in a 2D array. In table I, the column number is denoted by x, the row number is denoted by y and the element of the table is denoted by L. Then $T(x+16y)=L$.

Table I. PEDVS mapping function

No	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	6	12	18	24	30	36	38	39	41	42	45	48	60	63	66
1	72	84	96	120	126	132	144	156	168	180	183	186	192	204	210	216
2	240	264	276	288	312	324	330	336	348	360	384	408	432	456	468	480
3	492	504	552	576	600	624	636	648	696	744	768	780	792	840	888	912
4	936	984	1032	1056	1080	1128	1176	1200	1224	1272	1320	1344	1368	1416	1464	1488
5	1512	1560	1608	1656	1704	1752	1800	1848	1896	1944	1992	2040	2088	2136	2184	2232
6	2280	2328	2376	2424	2472	2520	2568	2616	2664	2712	2760	2808	2856	2904	2952	3000
7	3048	3096	3144	3192	3240	3288	3336	3384	3432	3480	3528	3576	3624	3672	3720	3768
8	3816	3864	3912	3960	4008	4056	4104	4152	4200	4248	4296	4344	4392	4440	4488	4536
9	4584	4632	4680	4728	4776	4824	4872	4920	4968	5016	5064	5112	5160	5208	5256	5304
10	5352	5400	5432	5464	5496	5544	5576	5608	5640	5688	5720	5752	5784	5832	5864	5896
11	5928	5976	6008	6040	6072	6120	6152	6184	6216	6264	6296	6328	6360	6408	6440	6472
12	6504	6552	6584	6616	6648	6696	6728	6760	6792	6840	6872	6893	6915	6936	6984	7016
13	7037	7059	7080	7128	7160	7181	7203	7224	7272	7304	7325	7347	7368	7416	7448	7469
14	7491	7512	7560	7592	7613	7635	7656	7704	7736	7757	7779	7800	7848	7880	7901	7923
15	7944	7992	8024	8045	8059	8074	8088	8136	8168	8189	8203	8218	8232	8280	8312	8333