Image Enhancement & 2D—TDI Technique of Infrared System

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ABSTRACT

2D-TDI (Two dimensions time delay Integral) technique usually be used to improve SNR (Signal to Noise Ratio) of infrared system, but the effect is not obvious when the delay time is not long enough. Several infrared image enhancement method based on 2D-TDI using gray transform has been put forward in this article. Testing results show these methods are superior to simple average method and can be implemented in real-time thoroughly. So they have high practical value.
keywords infrared system, real-time processing, image enhancement, 2D-TDI

1. INTRODUCTION

Infrared thermal imager is the instrument that uses the ray radiation of nature scenery. Only ray radiation exist, no matter in daytime in night, or under completely dark condition, it can become picture. The general transmission route of ray radiation is: Scenery ray radiation →Atmospheric Window →Optical System → Detector →Electronic Handling →Display. Each level passed by scenery ray radiation has caused the attenuation of radiation energy and at the same time added noise. For example the picture which obtained by thermal imager under rainy weather condition is fuzzier than under sunny weather condition because the energy of scenery ray radiation have been absorbed by raindrop. At the same time the raindrop itself produces radiation again which is a kind of noise for thermal imager and make the SNR of image decrease. Another example is that the electrical thermal noise produced by electronic handling module will add into the picture and make the SNR decrease. Therefore it is necessary to add electronic processor to suppress noise and improve the image quality in the rear level electronic processing.

2. DEFINITION OF 2D-TDI IMAGE ACCUMULATION

There are two methods of image accumulation. One is digital method and the other is analog method. Analog method accumulates analog signal directly. There is the special chip to implement
analog accumulation but not flexible in using. Along with the development of microelectronics technology, the integration and speed of electrical device become more and more high. It is completely feasible by using digital additional method which image should be digitization and storage. Now a 2D-TDI digital additional method is put forward as follow.

2D-TDI (Two dimensions time delay Integral) technique stores the frames of image then add them according to the corresponding pixel. 2D-TDI method needs at least two frames to add. Time delay make equivalent effect that resident time of photic dot on detector prolong consequently the SNR of system is improved. 2D means that frames accumulation is a two dimensions addition which is different from traditional serial accumulation of multi-detector.

If N frames need to accumulate with 2D-TDI method , corresponding memories are required in system to store N image frames. If series frames f1,f2,... fn participate addition on the time of t1, addition frames become f2,f3,... f_{n+1} on the time of t2 which only one frame has been freshed. This method solves the problem of successive image displaying and the frame rate is same with of input video. Usually the image after 2D-TDI processing will be well at displaying if destination move slowly enough(less than one pixel within n× 20ms),otherwise drag-tail of image will appear.

3 PRINCIPLE OF 2D-TDI TO IMPROVE SNR OF IMAGE

Suppose target is still or move slowly, SNR of thermal image will be improved after a period of delay integration because of the correlation difference between interframe signal and noise. If m frames of thermal images had been processed using 2D-TDI method, the signal power factor P of corresponding pixel is:

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$$P = (\sum_{i=1}^{m} Vi)^2 = \sum_{i=1}^{m} Vi^2 + 2\sum_{i=2}^{m}\sum_{j=1}^{i-1} C_{ij} V_i V_j \qquad (2)$$

Where Vi and Vj is signal voltage of interframe corresponding pixel, Cij is the interframe correlation coefficient ($0 \leqslant Cij \leqslant 1$).

In the process of using thermal imager, we find that the image noise mainly is some systematic uniformly distributed noises such as thermal noise, 1/f noise etc. We can reduce this kind of noise

$$N = (\sum_{i=1}^{m} V_{ni})^2 = \sum_{i=1}^{m} V_{ni}^{\ 2} = mV_n^{\ 2} \qquad (3)$$

with image accumulation technology to raise SNR and improve image quality. Since random noise is not correlative on time-domain and obey Poisson distribution, the correlation coefficient between noise Cij =0. After m frames 2D-TDI processing, the noise power factor N of corresponding pixel is:

Where Vni is noise voltage of interframe corresponding pixel, Vn is noise equivalent voltage.

For image signal , if target is still or moving distance is less than one pixel within m frames integration period, interframe corresponding pixel can be regarded as approximate equal and mark as Vs. So the interframe correlation coefficient between signal Cij =1. After m frames 2D-TDI processing, the image power S of corresponding pixel is:

$$S = (\sum_{i=1}^{m} V_{si})^2 = \sum_{i=1}^{m} V_s^{\ 2} + 2C_m^2 V_s^{\ 2} = m^2 V_s^{\ 2} \qquad (4)$$

Where Vsi and Vs is signal voltage of interframe corresponding pixel. So the image power SNR is:

$$SNR = S/N = \frac{m^2 V_s^{\ 2}}{mV_n^2} = \frac{mV_s}{V_n} \qquad (5)$$

Suppose original image power SNR_0 before processing is:

$$SNR_0 = V_s^{\ 2} / V_n^{\ 2} \qquad (6)$$

So we have:

$$SNR = m \cdot SNR_0 \qquad (7)$$

It can be seen that image signal power SNR has been improved m times after m frames 2D-TDI processing. So 2D-TDI technology can improve infrared image quality.

4 DATA PROCESSING METHOD OF 2D-TDI IMAGE ACCUMULATION

One problem of 2D—TDI method is that saturation produced by multi-frame accumulation cause the area besides saturation can not be showed. For example if the resolution of a D/A converter in 2D-TDI system is 8 bit, displaying image most have 256 gray levels. If gray level of input image is 64, gray scale of image become 256 after 4 frames accumulation and all gray levels can be displayed by monitor. If gray scale of image become 512 after 8 frames accumulation, only half part of total gray scale can be displayed and the other part information not displayed will be lost.

4.1 Accumulation average

To solve above-mentioned problem, the simplest method is to take average after frame accumulation. Suppose n image frames participate accumulation, noting as f1 f2, ··· fn separately, output image decide from formula(8).

Hardware realization applying this method is very simple which just cut out high 8 bit of addition result.

$$fout = 1/n \bullet \sum_{i=1}^{n} fi \qquad (8)$$

Experiment results using this method show that accumulation effect is not obvious until n is greater than 4. But when n is greater than 8, image after average accumulation has high contrast and low noise than the input image. The price of high n make the system need more memories and become complicated.

4.2 Accumulation slide window

In the actual using of thermal imager, on the condition of long distance and bad weather to make the target at weak energy, strong noise and low SNR, adopting 2D-TDI system to accumulate and output by no compression way, image contrast will be enhanced remarkably. Though because of the saturation of image have sacrificed partial image information, but the interested field of image has been enhanced. In order to find the goal that we are interested from whole dynamic range produced by accumulation, a slide window need to be installed. Gray level output without compression in the window while gray level output with compression out of the window. This method has considered both image global information and the requirement of enhancing weak goal. Suppose the gray level of the window is W, gray level of left end point of window is A, whole gray level is N=n*256 after n frames 2D-TDI accumulation, it transforms N gray level scale into 256 levels if window mode has been used. The gray level transforming function is shown as formula (9).

From formula (9), if W equals 256, it will be 0 or 255 besides window. Total displaying dynamic range limits in the window which make image information out of window be lost. A suitable balanced point between image information and enhanced effect need to be found.

$$H(r)=\begin{cases}\dfrac{256-W}{2A}r & 0<r<A \\ r-A+\dfrac{256-W}{2} & A\le r\le A+W \\ \dfrac{(256-W)(r-N)}{2(N-A-W)}+255 & A+W<r<N\end{cases} \qquad (9)$$

4.2 Local enhancement

Experiment results indicate that compression method make image information lost. Methods in which both enhancing effect and image information are considered and N gray levels are converted into 256 need to be found. Through proper gray level transforming function, we can attain this goal. We use the curve in Fig.1 to realize gray level transforming. The continuity of the curve guarantees the gray level being successive after transforming. Transforming function is shown as formula (10).

$$H(r)=\begin{cases}2\bullet(r-\mathrm{int}(r/128)\bullet 128) & \textit{if } \mathrm{int}(r/128) \textit{ is even} \\ -2\bullet(r-(\mathrm{int}(r/128)+1)\bullet 128) & \textit{if } \mathrm{int}(r/128) \textit{ is odd}\end{cases} \qquad (10)$$

5. HARDWARE REALIZATION OF 2D-TDI METHOD

2D-TDI system must contain memories to store digital image. In order to accomplish addition in real-time, parallel structure has been adopted. Operation data must be stored in advance, therefore n frames accumulation needs n frame memories. For example we use n = 4 to explain the principle of 2D-TDI processors. Its construction diagram is shown as Fig2. Video from thermal imager pass through lowing filter and amplifier then be converted into digital value by A/D (8 bit). At the same time video signal enters logic controller who splits synchronal signal to form all control signals needed by system. A ping-pang structure of frame memories has been used in which when odd field is in writing status, even field is in reading status and vice versa. This structure can realize reading and writing operation do not disturb mutual and reduce the speed requirement for memories. Only one memory had been written in and 4 memories had been read out at one field. When another field arrives, data has been written in another frame body and read from different another 4 memories. Four image frames have been stored in real-time with data circulating as this way. The result bits of four eight bits parallel addition is 11 bits. They are dispatched to a LUT made of a DUAL PORT RAM to provide 8 bits data to D/A. Another port of DUAL PORT RAM connect with microprocessor which translate

the keyboard information and change LUT function in real-time to implement algorithm.

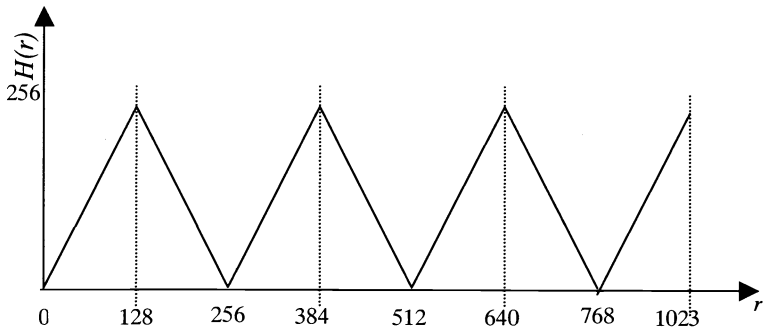

Figure 1 gray level transforming function of local enhancement

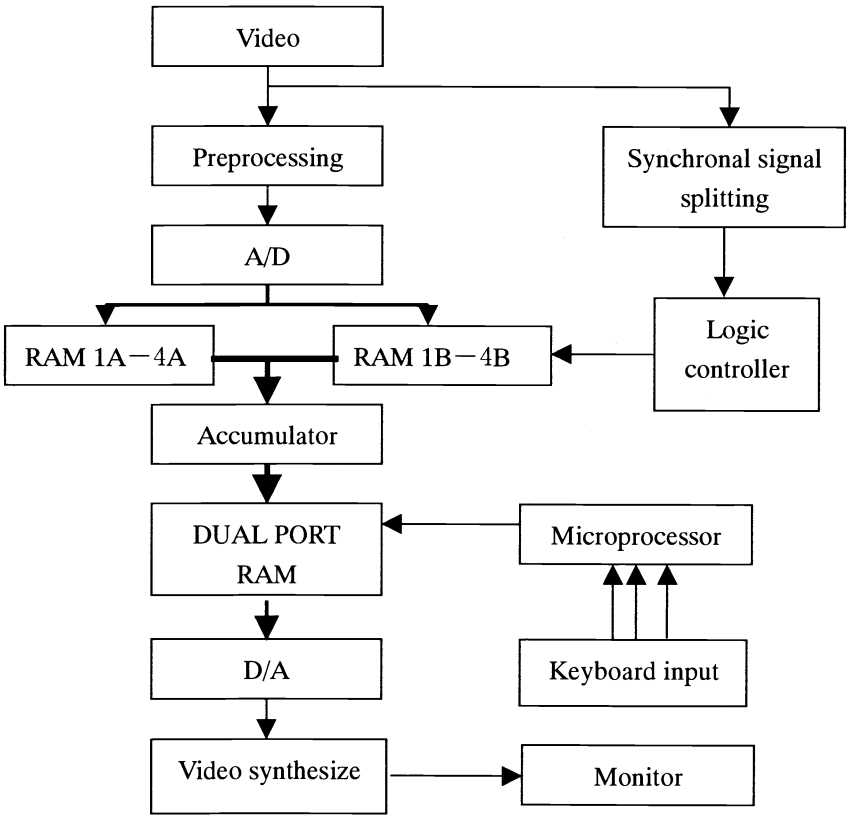

Figure 2 2D—TDI Processor Scheme

6. APPLICATION AND CONCLUSION

Fig3(a) - Fig3(h) are results that we use above-mentioned method to process image in 2D-TDI system. Notice that accumulation average method is not obvious to improve image quality. Gray level distance in window is bigger than that out of window shown as Fig3(b) and Fig3(f) which means image whose gray level in window has been enhanced more and at the same time whole image information has been considered in this method. When we use the window mode, we find that if value of A is too small, image lights; value of A is too big, image is dark again. This is the shortcoming of this method. When window is at its biggest width 256,

image whose gray level being in the window has been enhanced most. We can see that the plane in Fig3(g) is very conspicuous. The enhancement effect is obvious as show from the wheel outline of jeep in Fig3 (d) which use local enhancement technique. But this method is sensitive for noise and artificial looking because of gray level transforming function not monotonous increase.

Anyway, at the same time of 2D-TDI system reducing noise and raising SNR, through gray level transforming function to implement image enhancement can improve the capability of thermal imager on observation for weak goal. It is still in an experimental stage, only 4 frames 2D-TDI have been done. 8 or 16 frame 2D-TDI experiments still remains to test further.

7. REFERENCES

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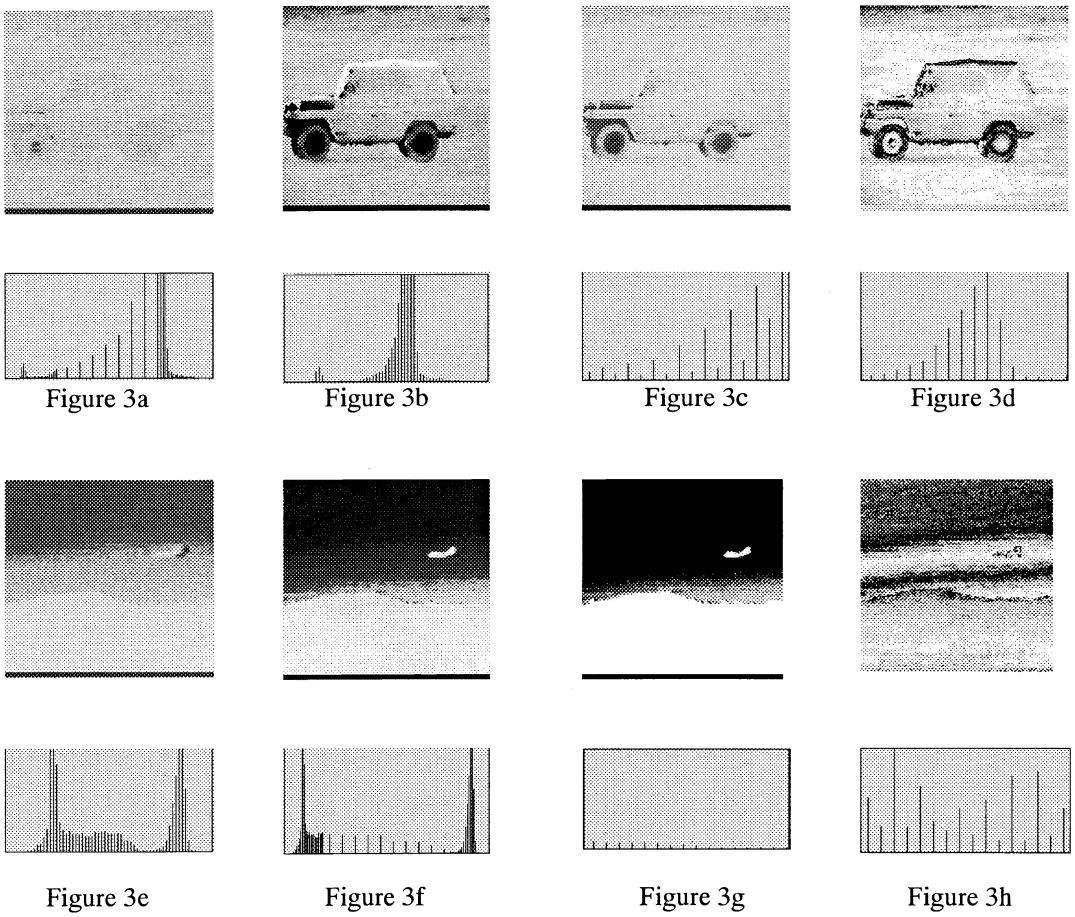

Figure 3a Figure 3b Figure 3c Figure 3d

Figure 3e Figure 3f Figure 3g Figure 3h

Figure 3 Results of Image Processing Using 2D—TDI System
(Accumulation Average a, e; Accumulation Slide Window b:
W=128, A=400, f: W=160, A=500, c, g: W=256, A=400; Local Enhancement d,h)