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VIDEO SIGNAL CORRECTION FOR SCANNING PHOTOCELL ARRAY IN THE IR-COMPUTER VISION SYSTEMS

ANDREEV, V[ictor] P[avlovich]

Abstract: *The method provides compensation of the influence of parameter spread of sensitive elements of the photo sensor array on the output signal. The method is based on statistical image properties and does not require embedding into the system of optical-mechanical scanning of reference radiation sources. The compensation with respect to sensitivity and dark components of photo sensor signals is performed. The results of experiments with real images and the program model of the scanning photo sensor array are presented.*
Key words: *photocell array, video signal, compensation*

1. INTRODUCTION

In computer vision systems a photocell array installed in an optomechanical scanning system is sometimes used as the video signal sensor. Such systems are most often used in design of IR vision devices. In robotics IR vision devices can be an extremely useful source of video information, especially in computer vision systems of specialized mobile robots, including those used by the Russian Emergency Situations Ministry (Pryanichnikov et al., 2009).

In scanning systems video signal is formed upon successive commutation of array photo sensors which are shifted as a whole in the direction perpendicular to the photo sensor position in the array. In the course of such scanning each photo sensor forms electric signal whose value is proportional to the radiation flux hitting the photo sensor through the objective. As a result, each photo sensor forms one image row.

In most cases the function of radiation transformation into the electric signal of the photo sensor can be described by the following linear model (Boltar et al., 1999):

$$U_i(x) = S_i \times E_i(x) + C_i \text{ , for } \boldsymbol{i} = 1,2,\ldots,N, \qquad (1)$$

where: S_i is the integral sensitivity of ***i***-th photo sensor;

C_i is the video signal component due to dark current;

$E_i(x)$ is the brightness of the optical signal scanned along axis ***x*** by ***i***–th photo sensor ($E_i(x) \geq 0$);

N is the number of photo sensors in the array.

Video signal in homogeneity, i.e., incongruence of the output signal $U_i(x)$ and the image $E_i(x)$, occurs due to the spread of sensitivities { S_i } and dark components { C_i } of photo sensors. This phenomenon is called structural or "geometric" noise of multielement radiation receiver. Multielement IR radiation sensors possess especially strong structural noise (Boltar et al., 1999).

Taking into account the linear character of photo sensor model (1), the video signal can be corrected:

$$U_i^{'}(x) = K_i \times \left[U_i(x) + R_i\right] \text{ , for } \boldsymbol{i} = 1,2,\ldots,N, \qquad (2)$$

where: R_i is the adaptive correcting signal compensating the in homogeneity of dark components of the video signal C_i ;

K_i is the amplification coefficient of ***i***-th amplifier compensating in homogeneity of the sensitivity S_i.

The process of video signal correction is naturally separated into two parts: one is the compensation of video signal in homogeneity using formula (2) which should be performed with the speed of query of array photo sensors, and the other is the calculation of correcting coefficients K_i and R_i, which can be performed with a lower speed.

2. STATISTICAL IMAGE MODEL

The standard method based on illumination of photo sensors by one or two reference radiation sources with different intensity (Bogomolov et al., 1987) is well known. The disadvantage of this method is low compensation precision due to high complexity of achieving homogeneous illumination, especially in the IR range and neglect of fluctuation noise of photo sensors and reference radiation sources.

The reference-free method based on statistic image properties is known (Oremorod, 1982). In this method the assumption is made that the image is a random function of brightness with the ergodicity property. However, this ergodicity property can be used only if "message segments" are sufficiently long, i.e., it contains several thousand frames.

In this study it is proposed to use the image model based on statistical properties of neighboring image rows. This makes it possible to increase the accuracy of calculation of correcting coefficients in the case of small realization length.

The image can be considered as *N* realizations (rows) with finite length (*X* = *L*) of the random brightness function $E_i(x)$, where ***i*** is the row number; these realizations possess the following properties.

1. The probability that within one frame the variances of the brightness function $D_i(E)$ and $D_{i+1}(E)$ for neighboring rows coincide (event $A_{i,i+1}$) is much larger than the probability that they differ (event $B_{i,i+1}$):

$$P(A_{i,i+1}) >> P(B_{i,i+1}) \ . \qquad (3)$$

2. The probability that within one frame the average values of the brightness function $\overline{E}_i$ and $\overline{E}_{i+1}$ for neighboring rows coincide (event $F_{i,i+1}$) is much larger than the probability that they differ (event $H_{i,i+1}$):

$$P(F_{i,i+1}) >> P(H_{i,i+1}) \ . \qquad (4)$$

3. Events $A_{i,i+1}$ and $B_{i,i+1}$, as well as $F_{i,i+1}$ and $H_{i,i+1}$, respectively, form the complete groups of events:

$$P(A_{i,i+1}) + P(B_{i,i+1}) = 1 \ ; \qquad (5)$$

$$P(F_{i,i+1}) + P(H_{i,i+1}) = 1 . \qquad (6)$$

The appropriateness of properties (3) and (4) follows from the fact that the real image possesses strong statistical coupling between neighboring rows of one frame. Properties (5) and (6) are evident.

3. DETERMINATION OF CORRECTING COEFFICIENTS

The following transition coefficient can be determined for each pair of neighboring photo sensors based on (3) and (5):

$$G_{i,i+1} = \sqrt{D_i(U)/D_{i+1}(U)} \ , \text{ for } \boldsymbol{i} = 1, 2, \dots, N\text{-}1, \quad (7)$$

where $D_i(U)$ is dispersion of video signal.

Substituting (1) into (7), we obtain the expression connecting the transition coefficient and the sensitivity of neighboring photo sensors:

$$G_{i,i+1} = \delta_{i,i+1} \times S_i / S_{i+1} \ , \text{ for } \boldsymbol{i} = 1, 2, \dots, N\text{-}1 \ , \quad (8)$$

where the multiplicative error is

$$\delta_{i,i+1} = \sqrt{D_i(E)/D_{i+1}(E)} \ . \quad (9)$$

Then property (3) can be written as:

$$P(\delta_{i,i+1} = 1) >> P(\delta_{i,i+1} \neq 1), \text{ for } \boldsymbol{i} = 1, 2, \dots, N\text{-}1 \ .$$

For $\delta_{i,i+1} = 1$ expression (8) connects the sensitivity of neighboring photo sensors via the transition coefficient $G_{i,i+1}$, which yields the iterative formula:

$$S_i = \begin{cases} S_k & , i = k; \\ S_{i+1} \times G_{i,i+1} & , i > k; \\ S_{i-1} / G_{i,i-1} & , i < k, \end{cases}$$

where $\boldsymbol{k}$ is the number of reference photo sensor.

The transition coefficients $\{ G_{i,i+1}^{\langle j \rangle} \}$ for each $\boldsymbol{j}$-th frame can be determined in terms of the values of output signals of photo sensors (1) using formulas (7).

It follows from (4) and (6) with account of (1), and (9) that the difference between the average values of brightness of neighboring rows of the image for $\boldsymbol{j}$-th frame is

$$\Delta\overline{E}_{i,i+1}^{\langle j \rangle} = \overline{E}_i^{\langle j \rangle} - \overline{E}_{i+1}^{\langle j \rangle} = \left(\overline{U}_i^{\langle j \rangle} - C_i\right) / S_i - \left(\overline{U}_{i+1}^{\langle j \rangle} - C_{i+1}\right) / S_{i+1} \ ,$$

which yields the expression for additive transition coefficient:

$$Q_{i,i+1}^{\langle j \rangle} = (C_i - G_{i,i+1} \times C_{i+1}) + S_i \times \Delta\overline{E}_{i,i+1}^{\langle j \rangle} \quad (10)$$

and

$$Q_{i,i+1}^{\langle j \rangle} = \overline{U}_i^{\langle j \rangle} - G_{i,i+1} \times \overline{U}_{i+1}^{\langle j \rangle} \ . \quad (11)$$

Property (4), as applied to this problem, can be written as:

$$P(\Delta\overline{E}_{i,i+1}^{\langle j \rangle} = 0) >> P(\Delta\overline{E}_{i,i+1}^{\langle j \rangle} \neq 0) \cdot$$

For $\Delta\overline{E}_{i,i+1}^{\langle j \rangle} = 0$ expression (10) connects dark parameters of neighboring photo sensors via the additive transition coefficient $Q_{i,i+1}^{\langle j \rangle}$, which yields the iterative formula for determination of the values of dark parameters (frame number $\boldsymbol{j}$ is omitted),

$$C_i = \begin{cases} C_k & , i = k; \\ Q_{i,i+1} + C_{i+1} \times G_{i,i+1} & , i > k; \\ (C_{i-1} - Q_{i-1,i}) / G_{i,i-1} & , i < k, \end{cases} ,$$

where $\boldsymbol{k}$ is the number of reference photo sensor.

Expression (11) makes it possible to determine the transition coefficient $Q_{i,i+1}^{\langle j \rangle}$ in terms of the video signal $U_i(x)$ and transition coefficients $\{ G_{i,i+1}^{\langle j \rangle} \}$ for each $\boldsymbol{j}$-th frame.

The accuracy of calculation of transition coefficients can be increased by simple averaging over $\boldsymbol{j}$ values of the parameters $G_{i,i+1}^{\langle j \rangle}$ and $Q_{i,i+1}^{\langle j \rangle}$ obtained for the frame sequence.

4. RESULTS OF COMPUTER SIMULATION

The process and results of simulation are described in most detail in (Lebedev & Lyong, 2007). Three digital black-and-white 512x512 bit 256 color images were used as initial data (Fig. 1).

Fig. 1. Initial digital images

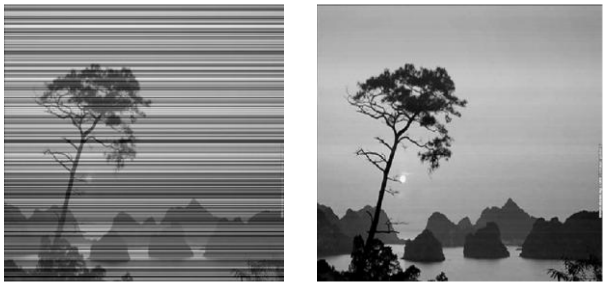

Fig. 2. Result of reading initial image by photo sensor array ($\boldsymbol{\delta}$=98) and result of correction using 3 initial images ($\boldsymbol{\delta}$=5)

For estimation of photo sensor array «quality» the parameter $\boldsymbol{\delta}$ was used:

$$\delta = 256 \times \Delta S + \Delta C \ ,$$

where:

$$\Delta S = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| S_i - S_{i+1} \right| \ ,$$

$$\Delta C = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| C_i - C_{i+1} \right| \ .$$

The spread of parameters of the initial photosensor array was $\boldsymbol{\delta}$=98. Figure 2a shows the result of reading one of the initial images of this array. For obtaining more accurate values of correcting coefficients it is necessary to use several frames ($J \geq 3$) which differ from each other by spatial brightness distribution (subject).

5. CONCLUSION

Results of simulation are shown high effect the method. This new adaptive method can be realized as in real-time special processor in thermal imaging systems. It is not required installation in an optomechanical scanning system of a reference radiation sources. For obtaining accurate values of correcting coefficients it is necessary to use several frames.

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