AN APPROACH TO ESTIMATING THE MOTION PARAMETERS FOR A LINEAR MOTION BLURRED IMAGE

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SUMMARY

Identification of motion parameters is an important issue in image restoration of a linear motion blur. Based on the human visual-motion sensing properties, an integrated approach with some known image processing techniques is proposed to the estimation of the direction and extent of motion on a linear motion blurred image. Experimental results confirm the feasibility of our approach.

Keywords: linear motion blur, image restoration, image processing

1. INTRODUCTION

Linear motion blur is a well-known type of degraded images. The early works on blur identification are focused on inherent regular pattern of zero-crossing due to point-spread function (PSF) in frequency domain [1, 2]. Although the zero-crossings are well-defined theoretically, they are obscured in practice. More recent works are usually based on an iterative approach, which is also involved in a complicated mathematical form [3, 4]. In this Letter, based on the properties of human visual-motion sensing [5], we present a feasible approach to simplify the problem of estimating the motion parameters, including motion direction and motion extension, for a linear motion blurred image.
2. PROPOSED APPROACH

The ability to interpret motion in space is a fundamental function of the human visual system. Watson and Ahumada [5] described some noticeable properties of human visual-motion sensing as follows: (1) locally perceived motion, (2) direction discrimination at threshold, (3) contrast sensitivity to moving patterns, (4) speed discrimination, (5) independent channels, and (6) summation. These may guide and motivate the construction of our motion sensor. Based on these properties, we integrate the “changing information” in a linear motion blurred image to estimate the motion direction (or motion angle, which will be used in the following) and the motion extension. Accordingly, the proposed approach is divided into two main parts corresponding to the estimation of motion angle and motion extension. A series of processing results are illustrated to simplify the presentation of our approach. A COUPLE image is shown first in Fig. 1(a). The linear motion blurred image with motion angle = 45° and extension \( L = 18 \) is shown in Fig. 1(b).

(A) Estimation of motion angle: The estimation of motion angle is briefly described as follows. The input blurred image (whose image pixel is denoted by \( g \)) is first transformed into an angled image (whose image pixel is denoted by \( a \)). The transfer relationship is given as below,

\[
a = \frac{255}{360°} \times \left[ \tan^{-1} \left( \frac{\Delta g_y}{\Delta g_x} \right) + Q(\Delta g_x, \Delta g_y) \times 180° \right],
\]

where

\[
Q(\Delta g_x, \Delta g_y) = \begin{cases} 
0, & \text{for 1st quadrant } (\Delta g_x \geq 0, \Delta g_y \geq 0) \\
1, & \text{for 2nd quadrant } (\Delta g_x < 0, \Delta g_y \geq 0) \\
1, & \text{for 3rd quadrant } (\Delta g_x < 0, \Delta g_y < 0) \\
2, & \text{for 4th quadrant } (\Delta g_x \geq 0, \Delta g_y < 0)
\end{cases}
\]
Δg_x and Δg_y represent the gradient x of g and the gradient y of g, respectively. In order to obtain a further useful angle information, we give some additional processings, they are binarization, nonsense signal removal, and interfering signal removal. Fig. 1(c) shows the final useful local information of motion angle in the blurred image.

Next, according to the property of locally perceived motion, the image shown in Fig. 1(c) is divided into many small blocks (12×12 pixels/block adopted in our algorithm), the angle information in each block is detected by Hough algorithm. Finally, the angle distribution of the whole image can be obtained as shown in Fig. 1(d), which has been smoothed to diminish the singular points. The peak of the angle distribution indicates the estimated angle 47° for the current example.

(B) Estimation of motion extension L: As the image moves faster, the image we see will be more obscure. It meets the human visual contrast sensitivity to moving pattern. Further according to the research [5], as the image moves faster, the high spatial frequency may be displayed on the decline. To measure the degree of blur (or the declined high spatial frequency), a scheme with logarithmic regression for the estimation of motion extension L is presented as follows. First, histogram equalization is applied to the linear motion blurred image shown in Fig. 1(b) to get more “edgy” information as shown in Fig. 2(a). Next, the more edgy image is split-and-merged by a quadtree structure to obtain the activity regions, which contains the noticeable information, as shown in Fig. 2(b). Based on the cumulative noticeable information filtered by the attention mechanism in human visual perception [6], each activity region must be scored first in order to quantify how high frequency has been declined. A score of the i-th activity region, whose standard deviation $\sigma_i >$ the threshold value $T (= 10$ in our experiments), may be ranged as $[1, 100]$ and experimentally designed by
\[ score_i = \min \left( \left\lfloor \frac{\sigma_i - T}{0.6} \right\rfloor + 1, 100 \right), \] (2)

where the operation \( \left\lfloor \cdot \right\rfloor \) takes the integer part of the inside calculated value.

Based on the computed scores for all activity regions, the distribution of all computed scores in the image may be shown by a histogram and its cdf (cumulative distribution function), as given in Fig. 2(c) and 2(d), respectively. Further based on the found cdf, a total score for the linear motion blurred image may be computed by the following formula

\[ total\_score = \sum_{j=1}^{100} \left[ 1 - (cdf_j)^{index} \right], \] (3)

where \( j \) is the score of an activity region by Eq. (2); \( cdf_j \) denotes the cumulative number of activity regions having the score \( \leq j \); and \( index (= 3 \text{ in our experiments}) \) is a constant. The computed total score, which represents an objective evaluation for an image quality, will be in the range \([1, 100]\).

Finally, based on our experiments and the logarithmic regression using the tool of “SPSS for windows,” the mapping relationship between the obtained total_score and the desired motion extension \( L \) may be expressed as

\[ L = \left\langle A \times \left[ \ln \left( \frac{total\_score}{B} \right) \right]^2 \right\rangle \] (4)

where \( A = 21.76, B = 89.57 \) are found in our current system, and \( \langle \cdot \rangle \) denotes the round operation. In the current example as shown in Fig. 2(d), the found total_score is 36.08, and the estimated motion extension \( L \) is 17,
3. RESULTS AND CONCLUSIONS

A set of eight popular images with $L = 6$–$18$ and different angles combining 126 experiments are used to test our approach. The performance is measured by the mean absolute errors ($MAE$) for the estimation of motion angle and motion extension. The results show that $MAE_{\text{angle}} \approx 1.51^\circ$ and $MAE_{L} \approx 2.67$ pixels can be achieved. As a conclusion, based on human visual-motion sensing properties, a feasible approach to estimating the motion direction and extension for a linear motion blur image has been developed and confirmed.

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REFERENCES


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Fig. 2  (a) Image after histogram equalization.  (b) Activity regions obtained by using a split-and-merge algorithm.  (c) Histogram of the computed scores.  (d) The corresponding $cdf$. 
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