Tutorial 2

Image and Video Processing

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All questions are examination standard.

1. MPEG2 is a digital compression standard for video transmission. A sequence is compressed using a 12 frame GOP with I,B and P frames such that the order of the first 6 frames is IBBPBBP.
   (a) What is a GOP, and what are I, B and P frames?
   (b) Why are B frames used in video compression schemes?
   (c) The graph in figure 1 shows the PSNR between an original sequence and its decoded version from an MPEG2 file encoded at 1 Mbit/second using an IBBP frame coding pattern. Explain which of the lines refers to the 1Mbit/sec sequence and which to the 128 Kbits/sec sequence.
   (d) Figure 2 shows one frame from a sequence in which a square object is moving at a slow velocity of [3,3] pixels per frame. On the left is superimposed a motion field generated using block matching (with 16×16 blocksize, and a zero MAE for motion detection), on the right is the true motion of the object superimposed. Why is the estimated motion field different from the true motion field along the edges and the interior of the object? Why is the estimated motion correct at the corners of the object?

2. A first step in any practical motion estimation process is to estimate which pixels in the image are in regions that are undergoing motion. An image sequence $G_n(h,k)$ is observed which has embedded film grain noise that corrupts the original clean image such that $G_n(h,k) = I_n(h,k) + e(h,k)$ where $e(h,k) \sim \mathcal{N}(0, \sigma_e^2)$. Where $\sigma_e^2 = 25$ and $I_n(h,k)$ is the clean original. The image under consideration is the same as that shown in Figure 2. The brightness of the square that is moving is 180 and the brightness of the background is 128.
   (a) A simple motion detection process is implemented which detects motion by thresholding the MAE (Mean Absolute Error) between corresponding pixels in two frames. For an MAE Threshold of 5, calculate the probability that a pixel is detected as moving when it is not. State any assumptions that you make. Estimate a suitable threshold for ensuring that the probability of false motion detection is less than 1%. A table of Complementary Error Function value is given in table 1.
   (b) To assist the process of motion detection the images are pre-filtered with a separable filter having coefficients $[1,\ 2,\ 1]/4$. Estimate the new probability of false motion detection for pixels that are in fact not moving, using a threshold of 5.

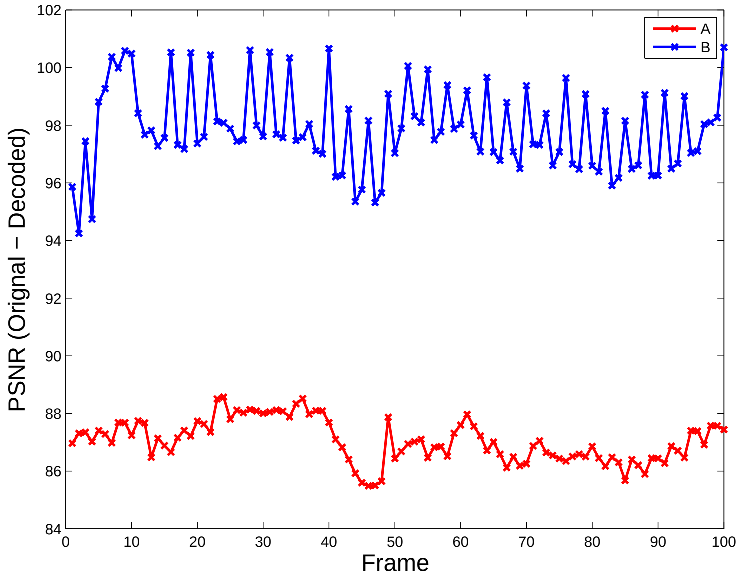

Figure 1: The PSNR between an original sequence and its decoded version from an MPEG2 file encoded at 1 Mbit/second and 128 Kbits/sec using an IBBP frame coding pattern.

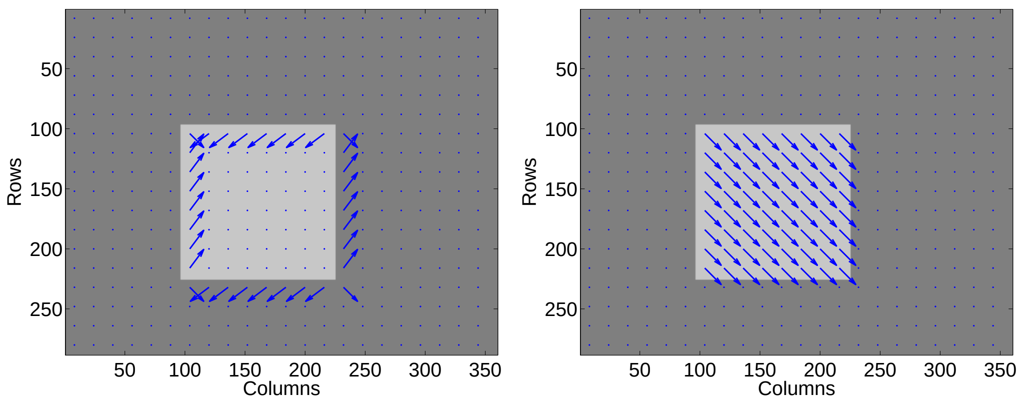

Figure 2: Left : A moving square with motion vectors estimated using blockmatching. Right: The same square with true motion.

Figure 3: An unusual 3/2 converted pulldown sequence. Rows left to right, Top : Frames 10-12, Bottom : Frames 13-15

(c) What is the disadvantage of filtering the images in this way as far as motion detection is concerned?

3. A film sequence at 24fps is converted to 30fps using 3/2 pulldown. A few frames of the resulting output sequence is shown in Figure 3. To convert from 3/2 back to 24p the 3/2 sequence needs to be detected and undone.

   (a) Explain why some of the images in the converted 3/2 sequence appear to have jagged edges.

   (b) Figure 4shows the MAE between consecutive fields of this pulldown sequence. This conversion has been performed in an unusual way and sometimes a frame is repeated. Design an algorithm that will detect which pairs of frames have been repeated. You can describe the process in words.

   (c) Why is motion estimation an integral process in frame rate conversion? Describe the process of symmetric block matching for this purpose.

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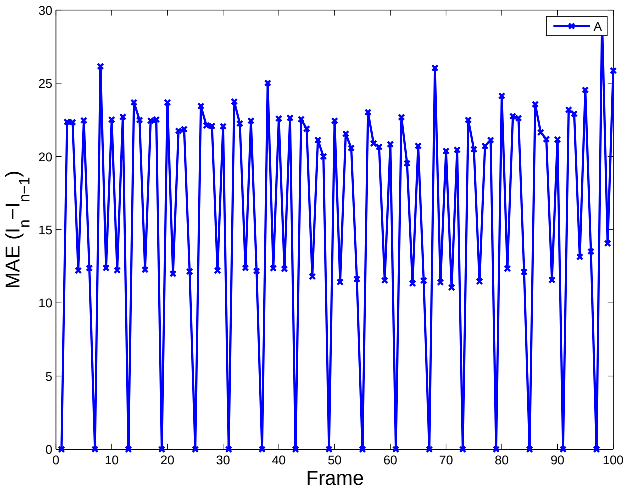

Figure 4: The MAE between consecutive frames in the 3/2 converted sequence.

x	erfc(x)	x	erfc(x)
0.10	0.8875	1.30	0.0660
0.20	0.7773	1.40	0.0477
0.30	0.6714	1.50	0.0339
0.40	0.5716	1.60	0.0237
0.50	0.4795	1.70	0.0162
0.60	0.3961	1.80	0.0109
0.70	0.3222	1.90	0.0072
0.80	0.2579	2.00	0.0047
0.90	0.2031	2.10	0.0030
1.00	0.1573	2.20	0.0019
1.10	0.1198	2.30	0.0011
1.20	0.0897	2.40	0.0007

Table 1: Values for the erfc(x) function. $\text{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^\infty \exp(-u^2)du$. Therefore, if x is normally distributed with mean 0 and variance σ^2, then $P(x > T) = \frac{1}{2}\text{erfc}\left(\frac{T}{\sqrt{2\times\sigma^2}}\right)$.