Homework 3

DIGITAL VIDEO - ECE 381K / BME 381J

Due April 4, 2023

Please show your work for more rational grading.

1 Block Motion Estimation

1. Using your knowledge from the lectures about Block Motion estimation, design a brute force (Full search) algorithm and implement it to estimate the motion between two consecutive frames. Use a block size of 16x16 with a search space of 48x48 in your implementation. Share your code in the HW submission.

2. Test and report your algorithm's accuracy w.r.t. ground truth motion vector using any sample from Middlebury Flow dataset.

2 Block Motion Estimation - continued

1. Improve the brute force approach by implementing a Logarithmic search in place of the exhaustive search. Use the same block size and search space as in Q1. Share your code along with results on the same sample image used in Q1.

2. Compare the number of computations in both the approaches.

3 Naive approach to Fleet Jepson

For a given video $f(\mathbf{x}, t)$ and a 3D Spatio-Temporal Gabor Filter $g(\mathbf{x}, t)$, the filter response of the video would be complex and can be written as:

$$s(\mathbf{x}, t) = f(\mathbf{x}, t) * g(\mathbf{x}, t) = \rho(\mathbf{x}, t) \exp\left[j\Phi(\mathbf{x}, t)\right] \tag{1}$$

Fleet and Jepson argue that signal phase $\Phi(\mathbf{x}, t)$ tracks optical flow in a very stable way using which they derive the OFCE as

$$\Phi_x a_x + \Phi_y a_y + \Phi_t = 0 \quad \text{where : } \mathbf{a} = \begin{bmatrix} a_x \\ a_y \end{bmatrix} = \begin{bmatrix} \dot{x}(\mathbf{x}, t) \\ \dot{y}(\mathbf{x}, t) \end{bmatrix} \quad \text{and} \quad \mathbf{x} = \begin{bmatrix} x \\ y \end{bmatrix} \tag{2}$$

Since this is not sufficient to compute the optical flow, they introduce another constraint:

$$\mathbf{a} = \alpha \mathbf{n}(\mathbf{x}, t) = \alpha \frac{\nabla\Phi(\mathbf{x}, t)}{|\nabla\Phi(\mathbf{x}, t)|} \tag{3}$$

1. Using the above information compute an estimate $\hat{\mathbf{a}}$ for the flow.

2. Show that $\nabla\Phi(\mathbf{x}, t) = \frac{Im[s^*(\mathbf{x},t)\nabla s(\mathbf{x},t)]}{|s(\mathbf{x},t)|^2}$ where $*$ denotes complex conjugate.

Note: $\nabla\Phi = (\Phi_x, \Phi_y, \Phi_t)$

4 Natural Video Statistics

1. Implement an algorithm to plot the histogram of divisively normalized co-efficients of a single frame from any given video. Test your code on any pristine video available in the UVG dataset. Explain and provide your code in the HW submission.

2. Now apply the cv2.GaussianBlur() filter, with a σ of 2 in both x and y direction, on the video and generate the histogram for the same frame using your implementation. Share the frame used, and the histogram plots obtained using both the pristine and the modified video-frame. Compare both the histograms and provide reasons for any differences in the distributions.

3. Change the σ of your GaussianBlur filter and share the obtained histograms for $\sigma = 5, 10, 20$. Observe and discuss any particular trend that is noticeable in the shape of the empirical distribution w.r.t. change in the parameters of the low-pass filter. Share the histogram plots to demonstrate your observations.