Exercise 13 for MA-INF 2201 Computer Vision WS22/23
09.01.2023
Submission deadline: 14.01.2023
Optical Flow

In this assignment, you are required to implement two methods (Lukas-Kanade, Horn-Schunk) for estimating optical flow between two given images. The data for the assignment is provided in the form of some images extracted from a video, as well as ground truth optical flows. The work should be done in the provided python script, which consists of the following parts:

- Data loading (already completed, see function `load_FLO_file()`
- Definition of the OpticalFlow class and its helper methods (already provided)
- Implementation of the Lukas-Kanade and the Horn-Schunk methods (to be filled by you, 6 points for each method)
- Implementation of the evaluation metrics: AAE and AEE. The output of both functions should contain both the average and 2D per-pixel metric maps (to be filled by you, 2 points for each metric)
- The main execution loop (provided) and the vizualization of obtained results (to be filled by you, 4 points). To complete this task, you will also need to complete the `flow_map_to_bgr()` vizualizer function. Requirements for the vizualization:
  - Run each of the two algorithms on all two pairs of provided video frames (0001-0002, 0002-0007).
  - For each run, compute the average AAE and AEE, and vizualize as RGB images the obtained optical flow, ground truth optical flow, per-pixel AAE, per-pixel AEE.
  - After vizualizations, summarize the computed metrics for each run in a tabular format.

Guidelines for the implementation of the optical flow algorithms:

1. **Lucas-Kanade optical flow**: Write your own implementation of the Lucas-Kanade optical flow as presented in the lecture. Use a 25×25 window in the algorithm.
2. **Horn-Schunck Flow**: Write your own implementation of the Horn-Schunck optical flow using an iterative scheme based on the Jacobi method as originally proposed by Horn and Schunck[1]. The iterative update rule is defined by

$$u^{(k+1)} = \bar{u}^{(k)} - \frac{I_x(I_x\bar{u}^{(k)} + I_y\bar{v}^{(k)} + I_t)}{\alpha^2 + I_x^2 + I_y^2}, \tag{1}$$

$$v^{(k+1)} = \bar{v}^{(k)} - \frac{I_y(I_x\bar{u}^{(k)} + I_y\bar{v}^{(k)} + I_t)}{\alpha^2 + I_x^2 + I_y^2}, \tag{2}$$

[1]B.K.P. Horn and B.G. Schunck, *Determining optical flow.* Artificial Intelligence, vol. 17, pp. 185 – 203, 1981

where

$$\bar{u}^{(k)} = u^{(k)} + \Delta u^{(k)} \quad \text{and} \quad \bar{v}^{(k)} = v^{(k)} + \Delta v^{(k)}. \tag{3}$$

You can approximate the laplacian $\Delta u^{(k)}$ and $\Delta v^{(k)}$ using the normalized Laplacian kernel

$$K = \begin{pmatrix} 0 & \frac{1}{4} & 0 \\ \frac{1}{4} & -1 & \frac{1}{4} \\ 0 & \frac{1}{4} & 0 \end{pmatrix}. \tag{4}$$

Set $\alpha = 1$ and initialize $u^{(0)}$ and $v^{(0)}$ with zero. Iterate until the difference of two flow fields in L_2 norm is less than 0.002, i.e. until

$$\sum_{i,j} |u_{i,j}^{(k+1)} - u_{i,j}^{(k)}| + |v_{i,j}^{(k+1)} - v_{i,j}^{(k)}| < 0.002. \tag{5}$$