Computer Vision II - Homework Assignment 4

Stefan Roth, Stephan Richter, Anne Wannenwetsch
Visual Inference Lab, TU Darmstadt

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This homework is due on July 12, 2017 at 9:00.
Please note that a late handin is not possible for this assignment!

Problem 1 - Horn-Schunck optical flow - 32 points

In this problem, you will implement a global optical flow algorithm. The test data for this assignment is from the Middlebury optical flow database, and you can evaluate your implementations with the corresponding ground truth data and the provided functions `read_flow_file` and `flow_to_color`.

In a first step, you implement several basic functions that will be needed for the optical flow estimation. For a quantitative evaluation of optical flow, we use the average endpoint (EP) error metric. The endpoint error for a pixel is defined as follows:

$$\text{EP error} = \sqrt{(u - u_{\text{gt}})^2 + (v - v_{\text{gt}})^2}, \tag{1}$$

where u, v are the horizontal and vertical components of the flow vector at a certain pixel and u_{gt}, v_{gt} represents the corresponding ground truth.

- Write a function `evaluate_flow(uv,uv_gt)` that computes the average endpoint error (AEPE) by averaging the EP error of all pixels.

  1 point

- The ground truth data uses the value $2e9$ for invalid pixels. Make sure to not include these pixels in your AEPE calculation.

  1 point

To evaluate the brightness constancy given an initial flow estimate uv_0, it is necessary to warp the second image I_2. Here, a so-called backward warping is performed, i.e. for each pixel (i, j) the corresponding brightness value is obtained at the position $I_2(i + u_0, j + v_0)$.

- Write a function `warp_image(im2,uv0)` that returns the second image warped by the initial estimate uv_0. Use bilinear interpolation.

  2 points

- Load images `frame10.png`, `frame11.png` and convert the data to grayscale. Load the ground truth data `flow10.flo` using the provided function `read_flow_file`. Apply the ground truth flow to obtain the warped second image I_2^w. Display I_1, I_2^w and the difference between both images. What do you observe?

3 points

To obtain an efficient optimization scheme for the optical flow estimation, it is necessary to linearize the brightness constancy assumption around an initial flow estimate uv_0 such that

$$I_2\big(i + u(i,j), j + v(i,j)\big) - I_1\big(i,j\big) \approx I_x \cdot \big(u(i,j) - u_0(i,j)\big) + I_y \cdot \big(v(i,j) - v_0(i,j)\big) + I_t. \quad (2)$$

Here, I_x and I_y denote the spatial derivatives of the warped second image I_2^w and $I_t = I_2^w - I_1$.

- Calculate I_x, I_y and I_t in the function `compute_grad_images(im1,im2,uv0)`. Use central differences to approximate the derivatives I_x and I_y and apply an appropriate boundary handling.

2 points

Now, you implement a simplified form of dense Horn-Schunck optical flow without the coarse-to-fine estimation.

- Implement the logarithm of an optical flow posterior assuming a pairwise MRF prior as well as a Gaussian distribution with parameter σ for likelihood and prior. In particular, write the function

  ```
  logposterior_HS(uv, uv0, Ix, Iy, It, lambda, sigma)
  ```

  to compute the log-posterior itself and

  ```
  grad_logposterior_HS(uv, uv0, Ix, Iy, It, lambda, sigma)
  ```

  to calculate its gradient. The parameter λ scales the smoothness or prior term and allows for a trade-off between the two components of the posterior.

6 points

- Implement a flow estimation algorithm

  ```
  flow_HS(im1,im2,uv0,lambda,sigma)
  ```

  performing an iterative minimization of the negative log posterior. Use Julia's `Optim` package to perform the optimization with `method = LBFGS()` and `iterations = 200`.

3 points

- Use the grayscale images `frame10.png`, `frame11.png` and estimate Horn-Schunck optical flow with parameter $\sigma = 1$. Write a function

  ```
  find_lambda(im1,im2,uv0,uv_gt,sigma)
  ```

  to determine an appropriate trade-off parameter λ, e.g. with grid search. Here, an evaluation of the AEPE w.r.t. the ground truth `flow10.flo` might be beneficial.

3 points

- Display your flow result using the provided function `flow_to_color` and calculate its AEPE.

1 point

- Estimate Horn-Schunck flow for a significantly smaller trade-off parameter λ_2 and for a significantly larger parameter λ_3. Display the results. What do you observe?

2 points

- Compare the AEPE of your results for $\lambda_1, \ldots, \lambda_3$. Do the visual results match the quantitative evaluation?

1 points

- Perform 5 iterations of the optical flow estimation using the previously obtained flow field $uv_{k-1}, k = 1, \ldots, 5$ as the initial flow estimate for the next iteration k. Find an appropriate parameter λ, evaluate the AEPE and visualize the results for each iteration. What do you observe?

6 points