Exercise 1: Optical Flow

Maj Šavli 63150278

I. Introduction

Optical flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and a scene. There exist many different methods for estimating optical flow, some of them estimating flow pixel by pixel, while others taking into the equation the flow of the whole image and trying to minimize specific flow functions. Two of such methods are called Lucas-Kanade method (LK method for short) and Hord-Schunck (HS method for short) method, which we implemented and tested on four pairs of real images.

II. Experiments

During implementation, we tested the methods on a rotated image of random noise. We can see the flow fields in bottom left and right corners of figure 1. Optical flow was estimated correctly by both methods, with minor differences.

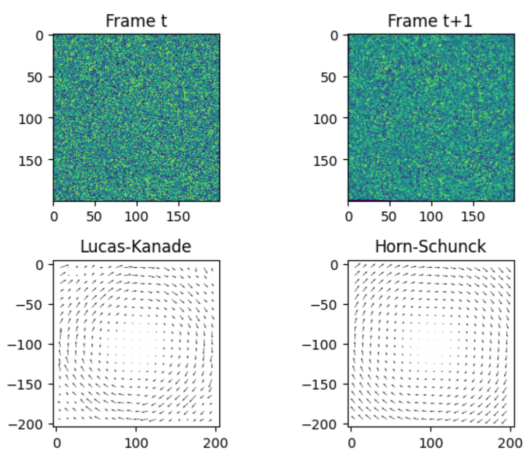

Figure 1: Optical flow estimation on random noise.

We want algorithm to work on a real images as well, so we tested the methods on three pairs of images, as seen in figures 2, 3, 4 and 5.

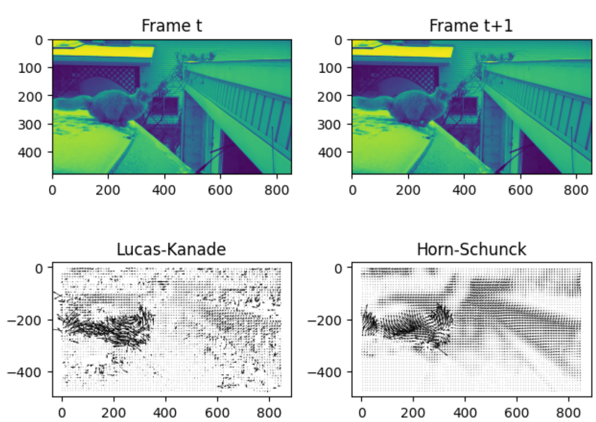

Figure 2: Cat jump optical flow estimation.

We can see a bigger difference between the methods in the figure 2 of a cat jumping. The both methods detected biggest motion in the left part of image, where the jumping cat is. We can also see that Horn-Schunck method yields more accurate and also denser flow vectors, which is also one of the method's advantages.

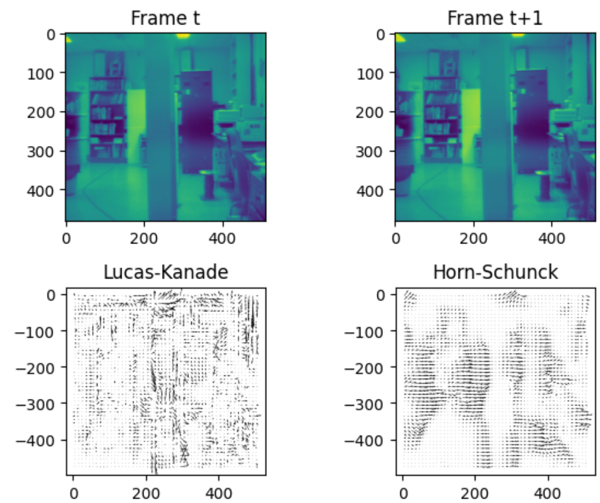

Figure 3: Moving through lab optical flow estimation.

The optical flow in figure 3 was in both cases biggest around the white pillar, which was moving the most. More vectors around pillar of the HS method point in the right direction than in LK method. However, in some areas the motion was not properly detected, due to very similar texture (white floor and pillar).

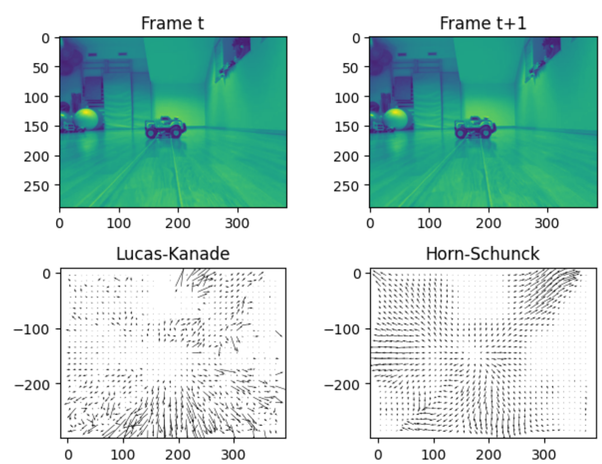

Figure 4: Moving towards toy truck optical flof estimation.

In the figure 4, the camera was moving towards the toy truck. We can see that both methods did estimate the flow properly, with HS method performing quite a lot better. It can be seen from flow field, that the motion is smallest in the center, where the truck is. The motion is the biggest on the border of the image, which HS method estimated quite good, except for the right part of image, which is again a consequence of similar texture (white wall).

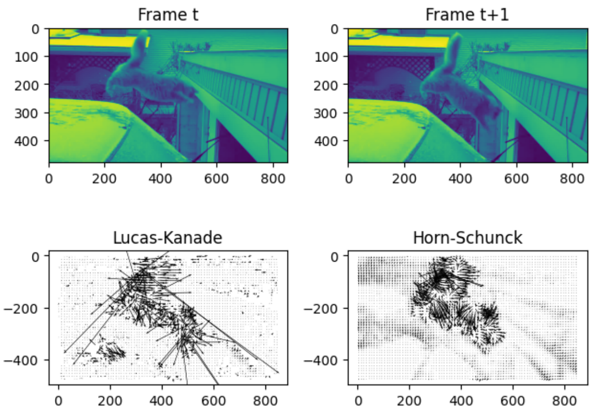

Figure 5: Failure case (fast cat jump).

Because of the small displacement vector assumption, LK method only works for small motions. In the figure 5, cat jumped and made significant motion. This resulted in bad result of the flow estimation in the areas of large motion (around the cat).

In the case of LK method, reliability of optical flow can be determined. This way, we can ignore the pixels, where the optical flow cannot be estimated properly. We can do this by at any pixel by computing the determinant of the matrix

$$A^T A = \begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix}$$

which is a covariance matrix of local gradients. Just by looking at the eigenvalues of this matrix, we can determine the quality of flow estimation. Both eigenvalues should be equally large, meaning there are strong gradients in horizontal and vertical direction and flow can be well estimated. If any of the eigenvalues is small, that means we cannot properly estimate flow in that direction.

Both performance and speed of methods rely on a couple of parameters. In LK method, we convolve image with a kernel of ones. As seen in figure 6, enlarging the kernel (to some extent) can improve the performance, since bigger neighborhood is taken into the equation. The optimal kernel size for all of our images was 10, bigger kernels resulted in complete failure.

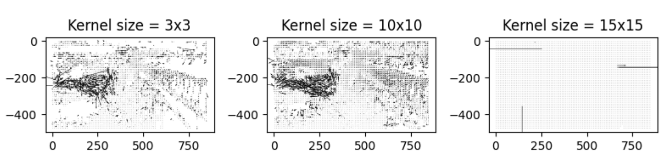

Figure 6: LK kernel size performance.

HS method rely on two parameters, number of iterations and alpha, which is a flow smoothness regularization constant. In the figure 7 we can clearly see that it requires a number of iterations, before HS method starts to show good results. In the pictures below, we can see that increasing alpha makes the flow smoother. Based on observations, we found out that the optimal value of alpha is 0.5 (used in the upper images of figure 7.

From the previous images we saw that HS method performs a lot better. However, as we can see in the figure 8, the HS method is a lot slower even for small number of iterations, which doesn't give good results. HS method runs for a specified number of iterations of until convergence of Laplacian matrices. Since Lukas Kanade algorithm is very fast, we can use it to initialize those matrices, resulting in faster convergence. To obtain similarity between matrices, we used cosine similarity. For the purpose of experiment, we ran HS method until one of the similarities reached value of 0.6.

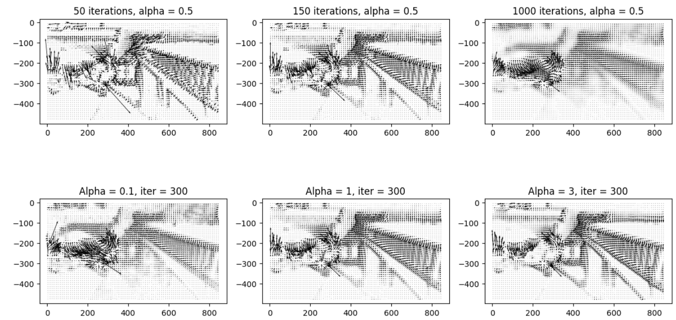

Figure 7: Impact of parameters on HS method performance.

	Lucas Kanade time (kernel size)	Horn Schunck time (n of iterations)
Cat jump	20ms (3)	704ms (50)
Cat jump	27ms (10)	2146ms (150)
Cat jump	50ms (15)	14127ms (1000)
Lab room	14ms (3)	437ms (50)
Lab room	18ms (10)	1218ms (150)
Lab room	40ms (15)	8170ms (1000)

Figure 8: Execution times of methods in miliseconds.

In the table below 9, we can see, that initializing with LK method really improves the speed of HS method. In the image of lab room the method with LK initialization executed five times faster than without it. Since in both cases matrices in methods converged to the same value, the performance is very similar. This means that it is a great improvement of HS method over speed.

	HS time in s (# of iter)	HS with LK init time in s (# of iter)
Toy truck	24,740 (3654)	12,12 (389)
Lab room	25,022 (1257)	4,801 (509)

Figure 9: Comparison between execution times of HS and improved HS

III. Conclusion

In this project we implemented two simple flow estimation methods and analyzed the experimental results. Both methods rely on some assumptions which can lead to failures. Scenarios, where motion vectors are large and pixel brightness is not constant, are more common than we would think. Moreover, both methods fail at estimating optical flow on the monotonous textures such as white walls, etc. Today, there exist many better and more thorough methods for optical flow estimation. However, in general, as we saw, in combination with LK method, HS method can be fast and generally performs good.