Optical flow: Lucas-Kanade & Horn-Schunck method

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I. Introduction

This report provides the experiments of two algorithms that determine optical flow, Lucas-Kanade and Horn-Schunck. These methods give us motion estimation from two consecutive images. These methods are used in computer vision areas such as motion detection, object tracking, etc. In the report we focus on the implementation of the two methods, their differences in performance and processing time. At the end we conclude the use cases of the algorithms.

II. Experiments

The methods used in this report were implemented in *Pyhton* programming language. In this report we experiment with Lucas-Kanade and Horn-Schunck methods for optical flow. For testing the methods and displaying results we used the provided source code.

The implementations of the two algorithms are further expanded with slight improvements. The table below II shows the parameters used in different approaches to the two methods. In the table LK stands for the Lucas-Kanade method and HS for Hans-Schunck method and nbh for neighbourhood.

method	num of it.	lambda	nbh
LK	/	/	3×3
LK with cov. matrix	/	/	3×3
HS	1000	0.5	/
HS improved	1000	0.5	3×3

We start the comparison of the methods with a random noise image 1. We notice that no major differences can be determined in the two methods. This makes it seem that the methods will perform similarly on all images which as we will see is not the case.

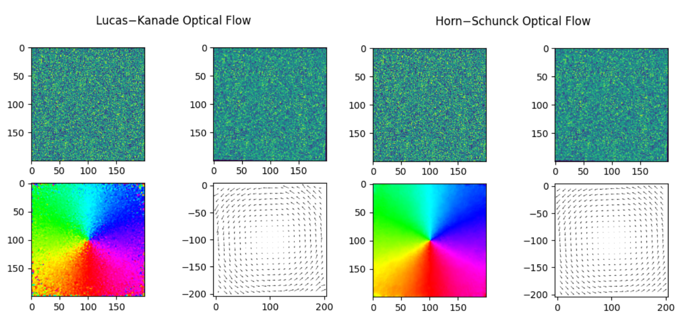

Figure 1. Optical flow in random noise image

1) *Testing the methods on images:*

For the testing of the methods we used already given pictures where we select two consecutive frames. In these pictures the object or camera is moved slightly and so the objects in the picture are in different positions.

The figure 2 shows the results of basic implementation of the two methods. We see that the optical flow is a lot smaller in the middle of the image compared to the corners. This indicates that the motion is mainly present in the corners.

It is important to notice that in the figure 2 we did not normalize the images to their size. This leads to slightly better but still overall bad results for the Lucas-Kanade method and worse results for the Horn-Schunck method. The improvements are shown in the next pictures.

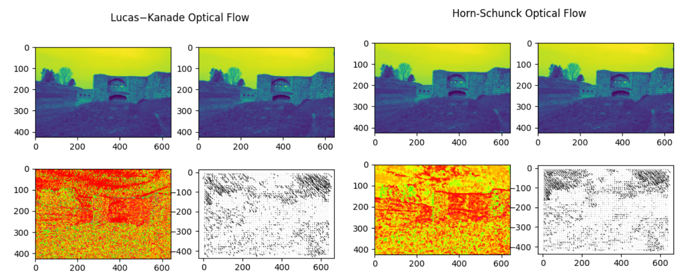

Figure 2. Optical flow of the basic methods for Lucas-Kanade and Horn-Schunck

As previously mentioned if we normalize the images at the start we get different results. The figure below 3 shows the results of the basic methods using normalisation of the images. We see that Lucas-Kanade method after normalisation does not return useful results whereas the results of Horn-Schunck method improve drastically.

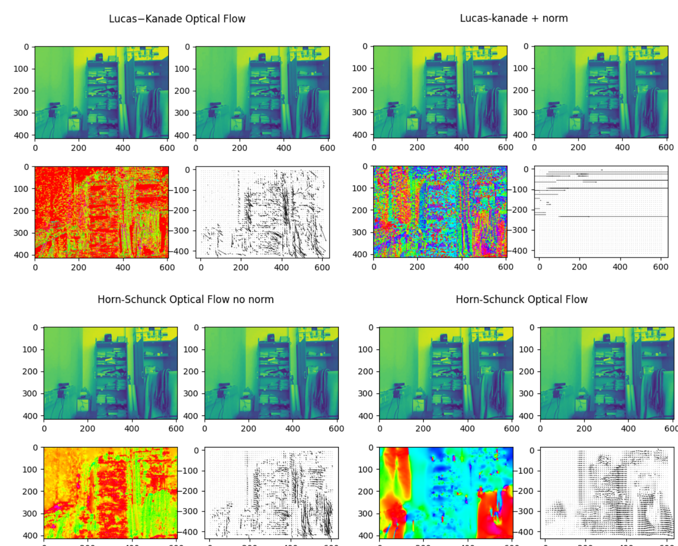

Figure 3. Optical flow of the basic methods with and without normalisation of the input images.

The last picture in the figure 4 we see similar results to the previous example. We notice that the normalisation of the image smooths the arrows and makes the result more precise. The results of Lucas-Kanade are again unusable.

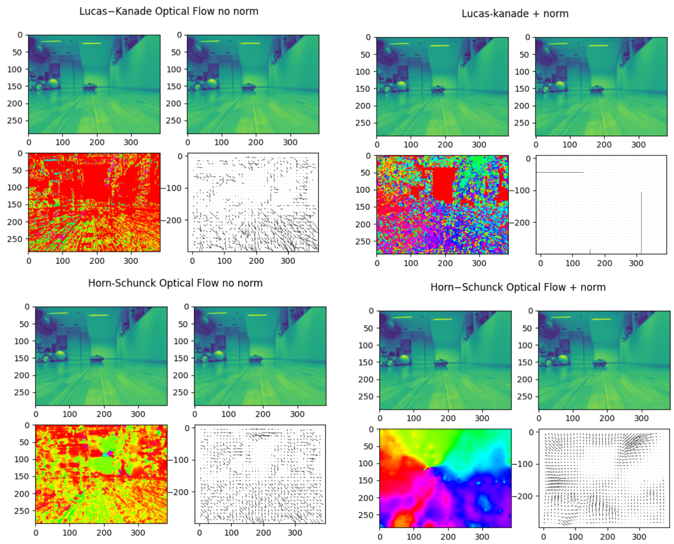

Figure 4. Optical flow of the basic methods with and without normalisation of the input images.

2) Improvement of the algorithms:
For the Lucas-Kanade method the flow we can compute the determinant of the A^TA matrix. This will help us with the reliability of the Lucas-Kanade optical flow method due to the fact that we can ignore the pixels where the optical flow cannot be estimated properly. In the mentioned matrix A^TA we need to calculate its eigenvalues. Both eigenvalues should be equally large or else we cannot estimate the optical flow. Where the ratio between the eigenvalues is bigger than the selected threshold we ignore those pixels.

The figure 5 shows the results after the implementation of the A^TA matrix. The method uses the same input values such as neighbourhood size with addition to other parameters we included threshold value of 0.0001 and ratio threshold value of 50.0. We notice quite an improvement in the results of the optical flow and the turquoise color on the bottom left picture shows that the optical flow could not be properly estimated in the majority of the picture.

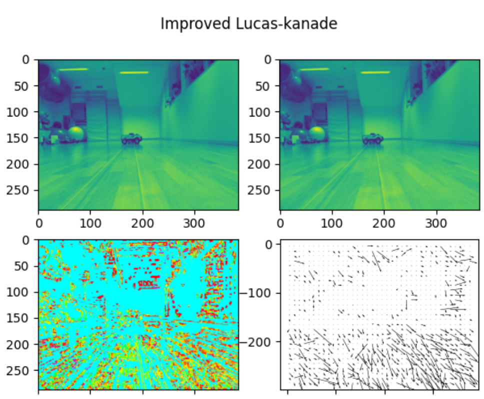

Figure 5. Lucas-kanade improved method with the use of A^TA matrix.

3) Parameters needed for Lucas-Kanade and Horn-Schunck method:
The Lucas-Kanade method only needs a neighbourhood which tells us the size of the surrounding area that affect the point. In contrast Horn-Schunck method uses lambda value which is used to determine accuracy of the local maximum and number of iterations.

The neighbourhood size in the Lucas-Kanade method is generally small since we would like to have the surrounding area small and compact (less can happen in small areas). If we increase the size of the neighbourhood we get smoother optical flow but not necessarily a more precise one. The figure 6 shows the differences of optical flow if the neighbour size is drastically increased on the right picture. We get a lot of flow where it was previously ignored.

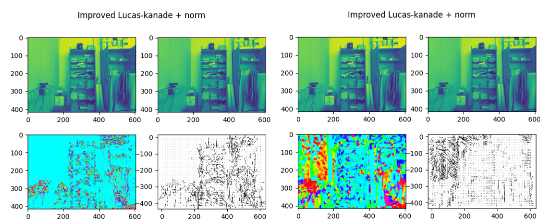

Figure 6. Differences in neighbourhood sizes. Left with size 3, right with size 13.

For the Horn-Schunck method lower lambda values will produce more accurate local maximums and higher number of iterations will return more precise results. Both parameters come at the price of time complexity which increases with previously mentioned parameter configurations.

4) Time measurements:
Time differences differ by a big margin so we have tested it on two different pictures. The table below II-4 shows the results.

We notice that the Lucas-Kanade algorithm performs the fastest which is expected. When calculating the A^TA matrix in the improved Lucas-Kanade algorithm takes a lot of time to compute all of the eigenvalues and determine if they are within the threshold or not.

The Horn-Schunck method depends on the complexity of the image. We would expect it to take the longest since the number of iterations is set to 1000. This shows in the office picture where it needed 9 seconds to complete the computations. When improving the Horn-Schunck algorithm with the output of Lucas-Kanade we notice a significant improvement time wise. This is due to the fact that if the u component converges within the number of iterations we break the loop of iterations.

method	car	office
Lucas-Kanade	0.01197	0.03092
Lucas-Kanade improved	2.36993	5.44214
Horn-Schunck	1.20193	9.06873
Horn-Schunck with L-C output	0.01596	0.04838

III. Conclusion

Horn-Schunck method even though it is more time consuming overall performs better than Lucas-Kanade. Both methods can be used when searching for the best possible results but Lucas-Kanade is more limited to specific pictures where the movements are not drastic and time is important. Lucas-Kanade can be greatly improved with the use of the covariance matrix of local gradients. The results between the two methods were comparable and the main differences were identified.