Practical work - Optical Flow

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1 Horn-Schunck Method

Each experiment has been made with a number of iterations of 200 for the Horn-Schunck algorithm. Each optimal alpha value was obtained using End Point Error (EPE) minimization.

1.1 Mysine

Here are our results:

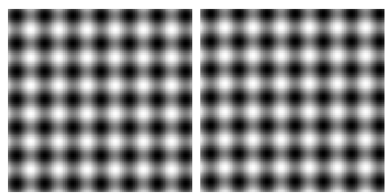

Figure 1: Mysine images

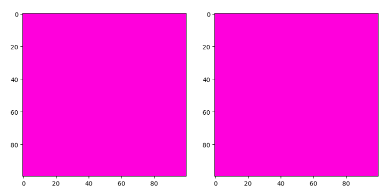

Figure 2: Optical flow prediction (left) and ground truth (right), $\alpha = 0.5$

/	EPE	RNE	REPE	Angular error
Mean	41.59	0.29	0.29	1.57
Standard deviation	0	0	0	$5e-3$

Figure 3: Table of statistics for Mysine dataset

When we look at the predicted image, we see that it is the exact same as the ground truth. Now let's dive into stats:

The value of EPE is high, which means that predicted vectors are far from their correct locations. Moreover, RNE and REPE of 0.3 implies that the norm (or magnitude) of the predicted flow vectors don't match the ground truth on average. A mean angular error of 1.57 radians suggests the predicted vectors are often pointing in the wrong direction compared to the ground truth.

1.2 Nasa

Here are our results:

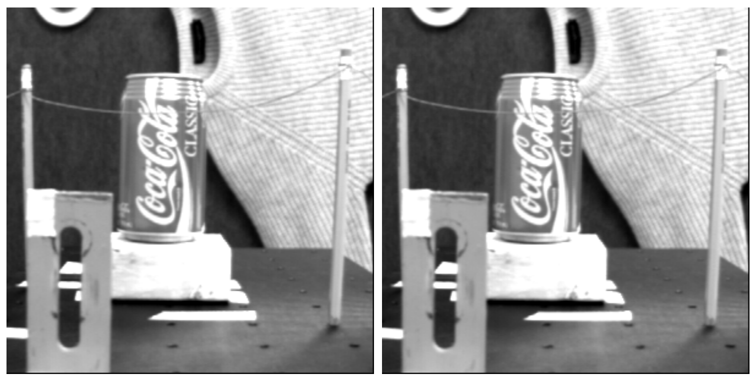

Figure 4: Nasa images

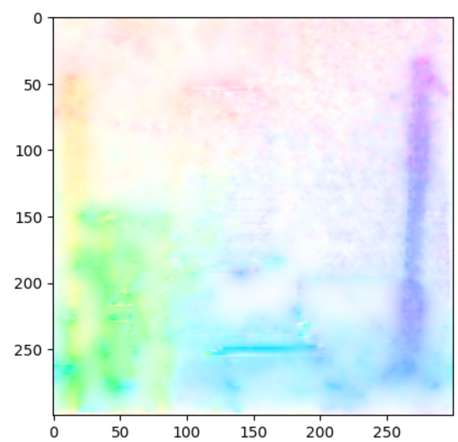

Figure 5: Optical flow prediction for Nasa (α=1000)

In the optical flow image, we see a range of colors, which implies a variety of motion directions and speeds within the scene. There are areas of green and yellow toward the bottom left part of the image, which indicate motion in a particular direction at a moderate speed. There's also a strong blueish-purplish area on the right side, suggesting a different motion direction and possibly higher speed.

The two frames here show that there is a slight zoom between the left one and the right one towards the thin, long and tall object on the right. Colors aren't that precise however, there are possible ameliorations here (like using another algorithm for instance).

1.3 Rubberwhale

Here are our results:

Figure 6: Rubberwhale images

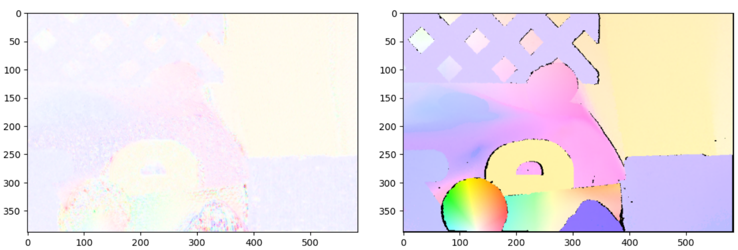

Figure 7: Optical flow prediction (left) and ground truth (right), α=1.83

/	EPE	RNE	REPE	Angular error
Mean	141852826136	1	1	1.57
Standard deviation	0	0	0	$1e-4$

Figure 8: Table of statistics for Rubberwhale dataset

When we look at the predicted image, we can see that if we constrast its colors, we can obtain a very similar optical flow to ground truth. Now, let's dive into stats:

The value of EPE is extremely high, which means that predicted vectors are far from their correct locations. This could also be due to issues with the data or fundamental limitations of the method applied to this particular scenario. However, RNE and REPE of 1 implies that the norm (or magnitude) of the predicted flow vectors matches the ground truth on average. A mean angular error of 1.57 radians suggests the predicted vectors are often pointing in the wrong direction compared to the ground truth.

1.4 Rubic

Here are our results:

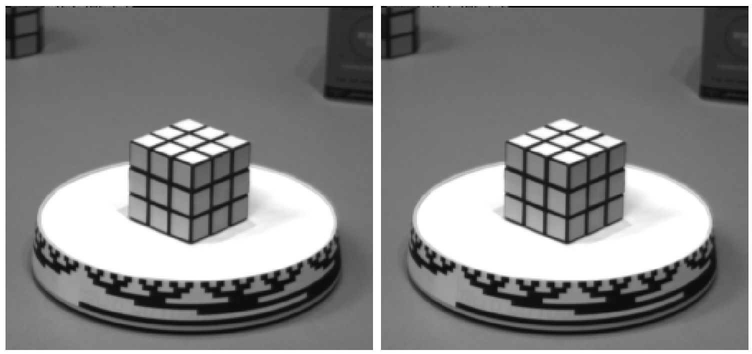

Figure 9: Rubic images

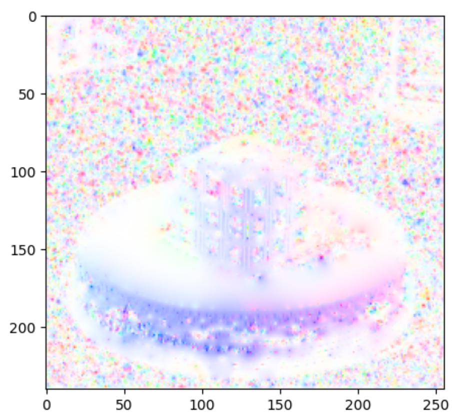

Figure 10: Optical flow prediction for Rubic (α=0.1)

It appears that the optical flow is predicting movement around the central object, which is the cube. The colors seem to radiate outward from the center of the stand, suggesting there is a rotational motion involved. The bright colors and strong patterns indicate significant predicted motion, especially around the base of the stand, which suggest the cube is moving between the two grayscale images. There is also a lot of noise around rubic's cube and its plate. This is likely due to the α regularization, which was maybe too low.

As seen in the course, the two frames come from a video where rubic's cube is effectively rotating on its plate, which means that optical flow succeeded.

1.5 Square

Here are our results:

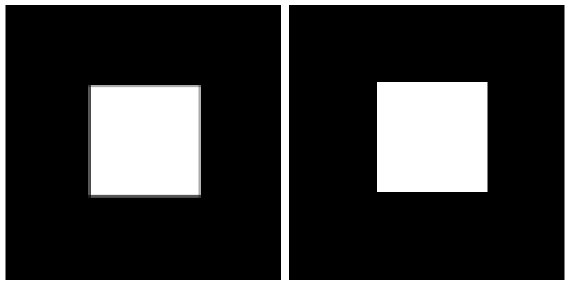

Figure 11: Square images

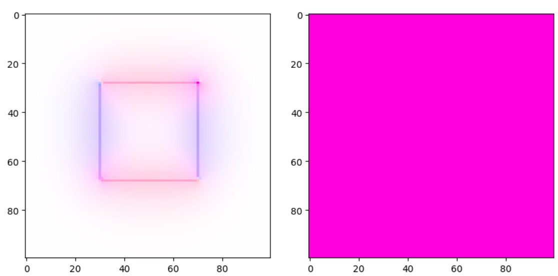

Figure 12: Optical flow prediction (left) and ground truth (right), $\alpha = 1e-4$

/	EPE	RNE	REPE	Angular error
Mean	183.7	0.95	0.97	1.57
Standard deviation	0	0	0	$3e-3$

Figure 13: Table of statistics for Square dataset

When we look at the predicted image, we see that some motion is predicted around sides of the square. Ground truth seems weird with this whole pink filled square. Now let's dive into stats:

The value of EPE is high, which means that predicted vectors are far from their correct locations. However, RNE and REPE of nearly 1 implies that the norm (or magnitude) of the predicted flow vectors matches most of the time the ground truth on average. A mean angular error of 1.57 radians suggests the predicted vectors are often pointing in the wrong direction compared to the ground truth.

1.6 Taxi

Here are our results:

Figure 14: Taxi images

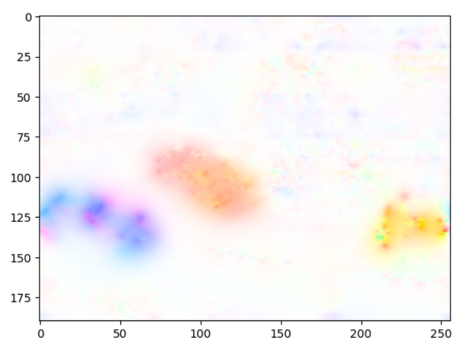

Figure 15: Optical flow prediction for Taxi (α=1000)

In this optical flow, colors concentrate on the three cars which are moving towards left for the two left ones and towards right for the cropped one on the right. The cropped one is less visible on the optical flow image, meaning that it moved less than the two other cars, but regarding the scenario it seems weird (because one other car is turning on its right and the other has to adjust its speed to pass this car). This is likely due to the fact that this cropped car is black.

1.7 Yosemite

Here are our results:

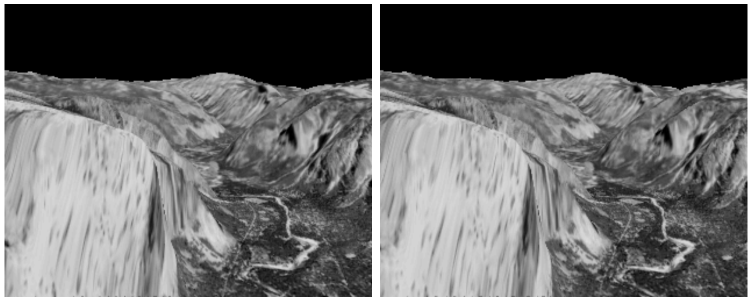

Figure 16: Yosemite images

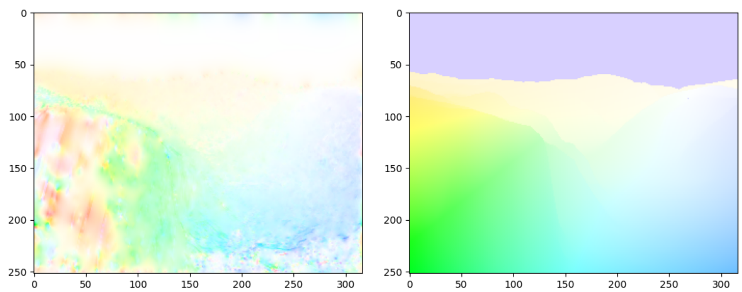

Figure 17: Optical flow prediction (left) and ground truth (right), $\alpha = 752$

/	EPE	RNE	REPE	Angular error
Mean	511.4	0.91	0.94	1.57
Standard deviation	0	0	0	$1e-3$

Figure 18: Table of statistics for Yosemite dataset

When we look at the predicted image, we can see that if we constrast its colors, we can obtain a very similar optical flow to ground truth (even though there are some noisy parts). Now, let's dive into stats:

The value of EPE is high, which means that predicted vectors are far from their correct locations. However, RNE and REPE of 0.91 and 0.94 implies that the norm (or magnitude) of the predicted flow vectors matches most of the time the ground truth on average. A mean angular error of 1.57 radians suggests the predicted vectors are often pointing in the wrong direction compared to the ground truth.

2 Lucas-Kanade method

The Lucas-Kanade method is based on the assumption that the optical flow, or the apparent motion of pixels, is constant in the immediate vicinity of each pixel. This assumption allows reformulating the optical flow problem into a system of equations that can be solved using the least squares method.

The advantages of this method include:

- Simplicity of implementation.
- Resistance to noise. By considering a neighborhood of points for the flow calculation, this approach can reduce the impact of outliers, unlike methods that process pixels independently.

However, the method has certain disadvantages:

- Linearity assumption: The method presupposes a linear relationship between the pixels at different times, which may not hold in scenarios involving complex or rapid movements.
- Aperture problem: The velocity field is calculated from the image intensity gradient, which can be problematic in uniform intensity areas, such as surfaces with a smooth texture.

The method depends on a hyperparameter: the window size n. To optimize this value, we used a Bayesian optimization approach, based on data for which the exact solution (ground truth) was known. The objective was to minimize the root mean square error (RMSE) between the velocity field estimated by the method and the ground truth. This technique determined that the optimal window size is $n = 36$. Something that can be intersting to point out is that the metric used as an objective for the bayesian optimisation does not need to be differentiable, which allows to use metrics that could be specific to the use case (For instance the AAE could be used).

Looking at the results, the algorithm seems to successfully generate a smooth vector field, which can be attributed to the "patch" approach.

However, the patch approach has its limitations. As we can observe in the "square" image, a too large **n** might lead to a loss of precision. Larger patches tend to average out the motion vectors over a greater area, potentially smoothing over the details and nuances of the movement within the image.

Additionally, the predicted vector field is expected to have a blank or neutral center, indicating no motion; yet, this is not observed in the results.

-	EPE	RNE	REPE	Angular error
My syne	67.88	0.2	0.6	1.57
Square	193.38	0.24	0.62	1.57
Yosemite	363.15	0.45	0.77	nan

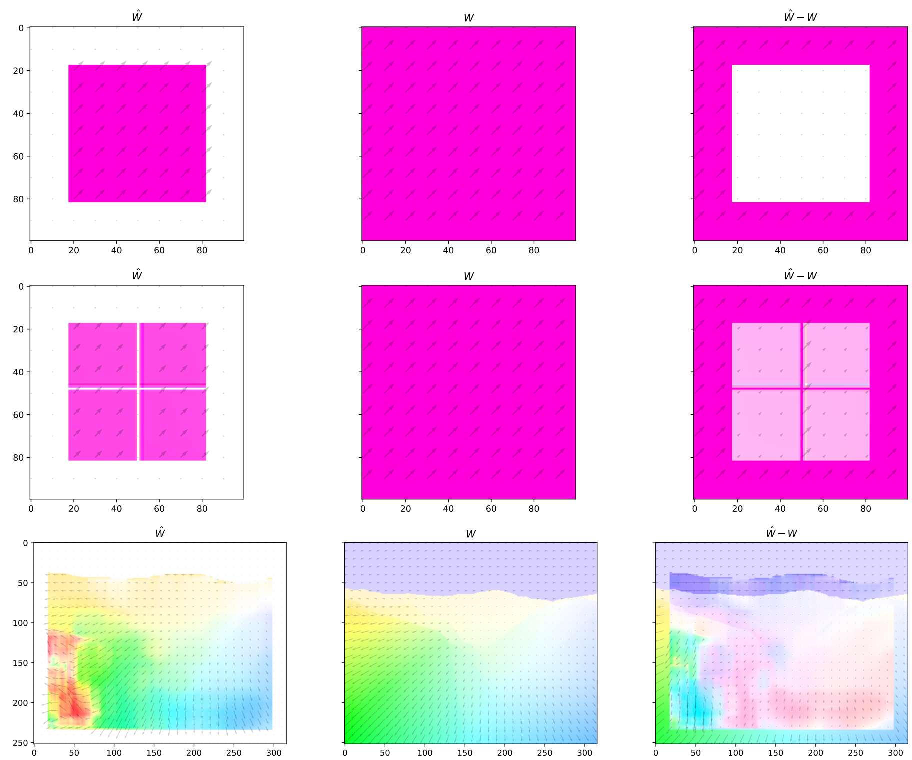

Figure 19: Images used to find an optimal value for **n**.

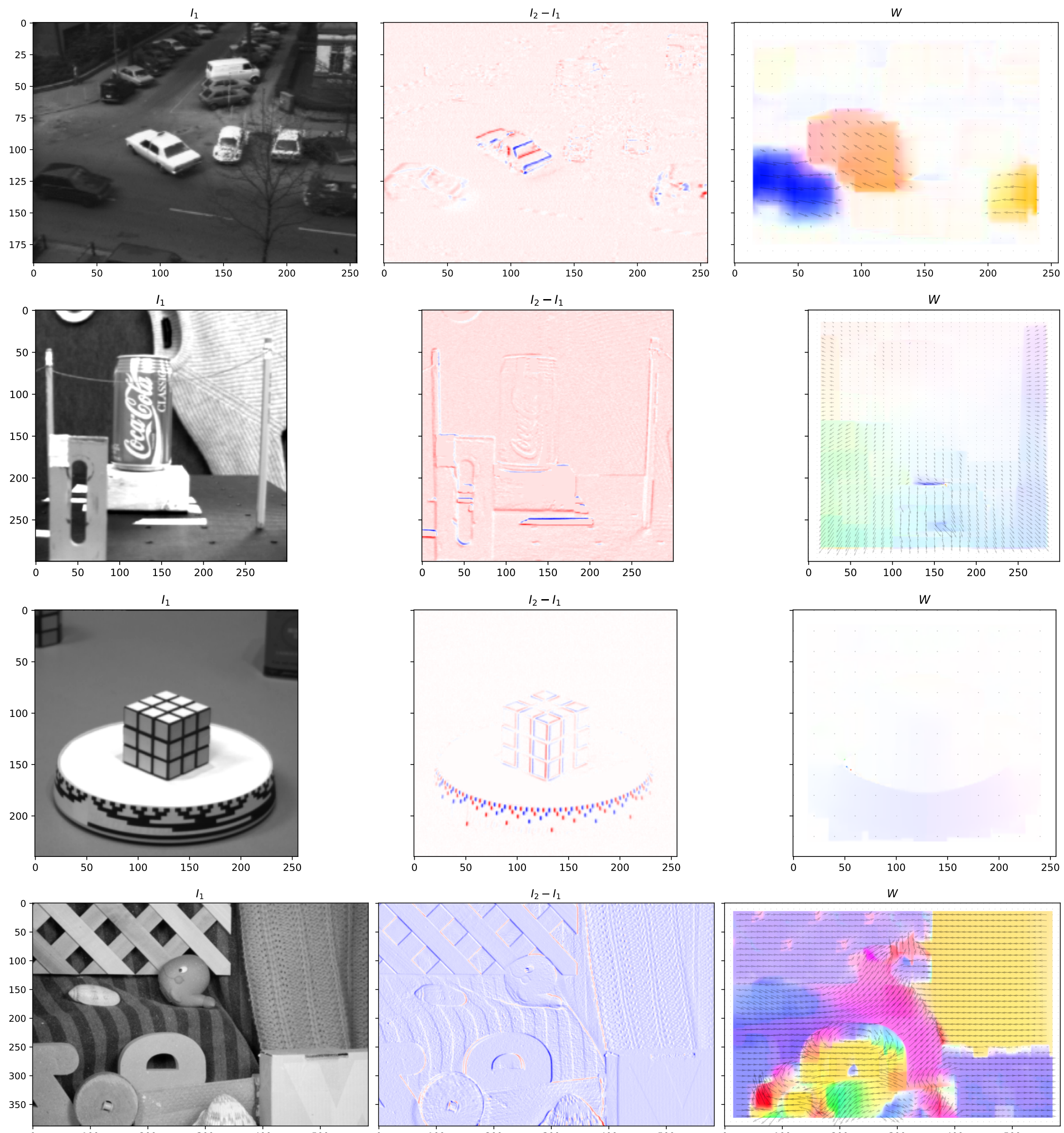

Figure 20: $\hat{W}$ obtained using the Lucas-Kanade method with **n=36**.