1.1 Thought Experiments

1. The number-one use of optical flow in visual effects is for retiming a sequence — speeding it up or slowing it down.Describe how optical flow could be used to create a slow-motion video. You can find the answer in Amazing Slow Motion Videos With Optical Flow Video on YouTube.

Ans

Optical flow helps to estimate the motion of objects in the video. Using this idea, we can create some extra frames of original video that are not present in the video. We can use the technique of interpolation to estimate the new frame using two consecutive frames. Optical flow helps in this by estimating the flow of objects in the video. Now when we have extra frames, we can create a smoother slow motion video.

It's movie time now! Let's watch an epic movie clip from one of the Academy Award-winning movies for Best Visual Effects - The Matrix (1999).

2. In The Matrix, one of the most remembered, iconic use of the tactic comes during the rooftop scene where Neo effortlessly dodges one bullet after another.(Re-)watch "Bullet Time" here and explain briefly how optical flow is used here. You may also find this video on bullet-time interesting.

Ans

Slow motion in The Matrix is generated by combining various camera shooting strategies. One is to capture different viewpoints from different angles by multiple cameras and second is to use interpolation to add new frames of video which makes smoother video. This was achieved by using several cameras to capture the 360 degree view of the scene at different angles and different camera centers. For this, the actor shot multiple scenes which covered the view in wide angle and they used interpolation to get new frames from actual frames.

3. Consider a Lambertian ball that is: (i) rotating about its axis in 3D under constant illumination and (ii) stationary and a moving light source. What do the 2D motion field and optical flow look like in both cases?

Ans

(i) Since the ball is rotating about its axis in 3D under constant illumination and assuming the ball has a smooth surface , It is not possible to identify new features as it will appear that the ball is static as it has the same features all over it. Here No optical flow but there will be some 2D motion field.

(ii)Since the ball is static and the light source is moving , Illumination pattern will be moving around the ball and it will appear that the ball is rotating as the shadow or illumination pattern will be changing over the surface . So here 2D motion field is not moving but we will have optical flow in this case

1.2 Concept Review

1. What does the objective function imply about the noise distribution?

Ans

In optical flow, the objective function is to estimate the velocity of objects in the frame. It assumes that surrounding pixels Intensities in the given window are constant. For noise distribution we apply Gaussian Blur to smooth the image. This is because the Optical flow objective function does not account for noise distribution.

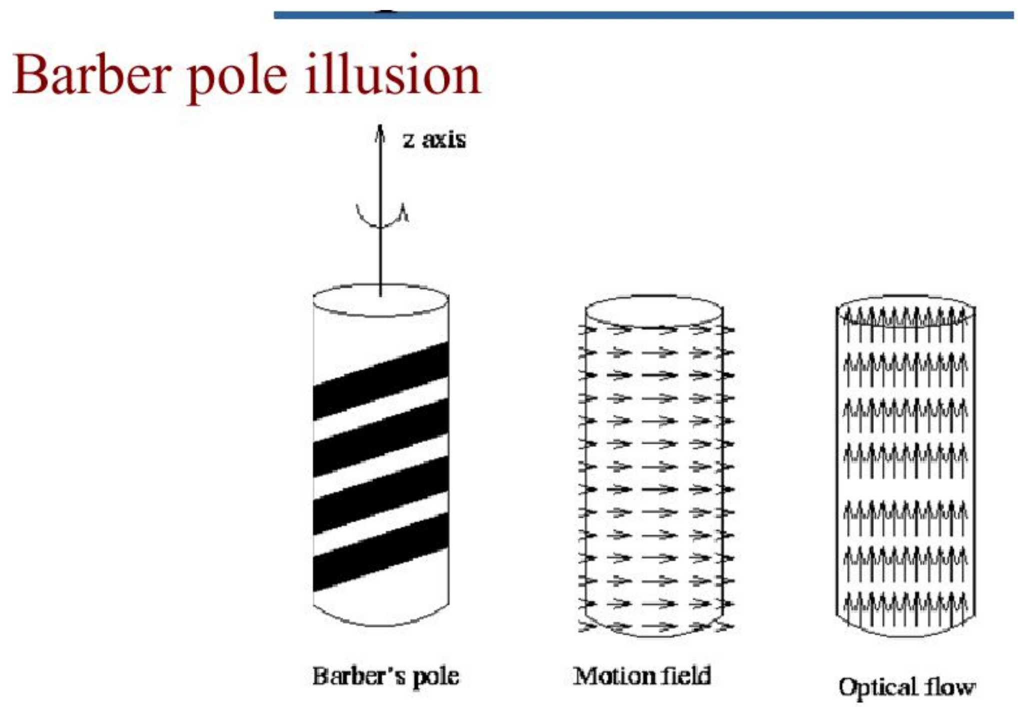
2. In optimization, why is the first-order Taylor series approximation done?

Ans

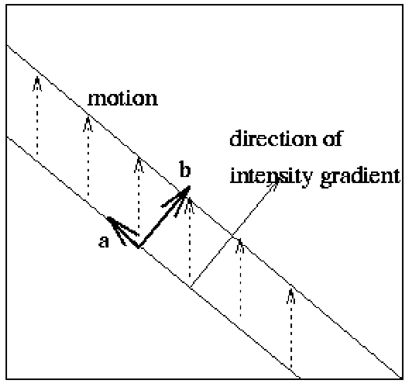
It is done to make the calculation easier. It is valid because we are assuming that between two consecutive frames , the displacement of objects is very small and the intensities remain constant . It helps as the higher order derivative term becomes near to zero, hence eliminated and we are left with only the first order term.

3. Geometrically show how the optical flow constraint equation is ill-posed. Also, draw the normal flow clearly

Ans



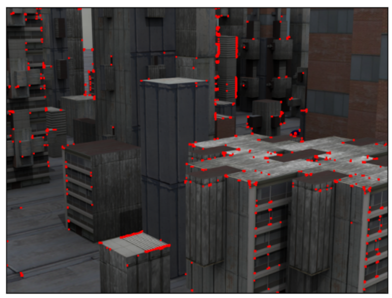
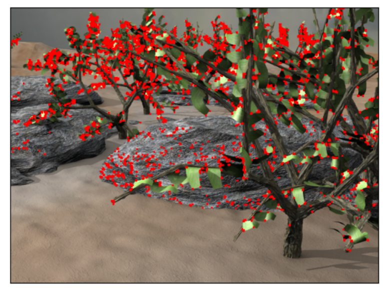
Generally, optical flow corresponds to the motion field, but not always. For example, the motion field and optical flow of a rotating barber's pole are different, as illustrated in the figure . We are only able to measure the component of optical flow that is in the direction of the intensity gradient. We are unable to measure the component tangential to the intensity gradient.



2.1 Keypoint Selection: Selecting Pixels to Track

Visualize the detected pixels superimposed on the images for at least one image from each of the given sequences

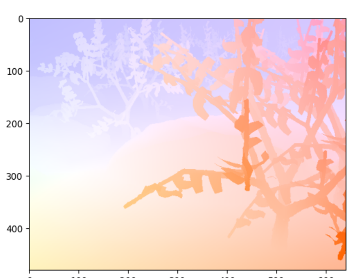
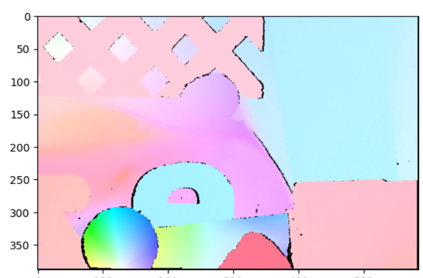
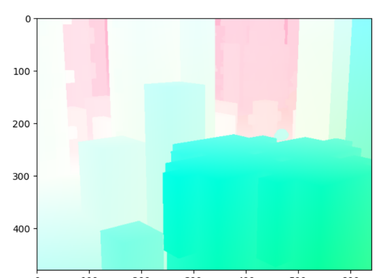
Ans

Here we can see the different corner points in different images. We can see that some points have been misidentified as corner points.

2.2 Visualizing the dense optical flow of the .flo filesgiven

Ans

2.3 Analyzing Lucas-Kanade Method

1. Why is optical flow only valid in the regions where local structure-tensor ATA has a rank of 2? What role does the threshold τ play here?

Ans

Optical flow is only valid in the regions where local structure tensor ATA has a rank of 2. This is because 2 eigenvalues of the matrix signify the change in x and y direction which signify a point of interest similar to Harris Corner concepts. So it ensures that there is enough intensity gradient information in the region to accurately estimate the movement of the pixels.

With the help of threshold we put a lower bound on the smallest EigenValue of ATA.
It helps to identify the corners or features which can be easily tracked. The threshold defines the pixels for which optical flow is calculated. The threshold τ is used to determine the regions where the local structure tensor has a rank of 2 thereby excluding regions where the intensity gradient information is not sufficient.

2. In the experiments, did you use any modifications and/or thresholds? Does this algorithm work well for these test images? If not, why?

Ans

If we increase the threshold value the regions of interest where we need to find the optical flow will decrease and vice versa. The algorithm works well for some test images of the dataset. Although in some cases it wrongly identifies the point of interest. This might be due to the presence of noise such as bad lighting conditions etc. Gaussian smoothing can help in this regard. Apart from that I have used , distance threshold to keep spacing between different vectors in the images.

3. Try experimenting with different window sizes. What are the trade-offs associated with using a small versus a large window size? Can you explain what's happening?

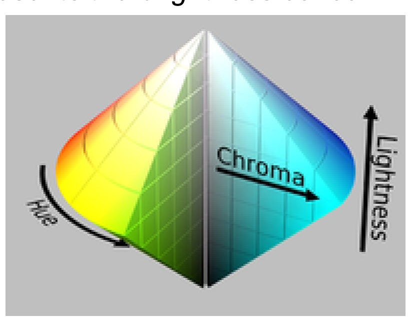
Ans

By experimenting with different window sizes, we see that error is almost constant and varying a little here but in general as we increase the window size, the Image Illumination constant condition seems to not hold very well. So the performance decreases.

4. Did you observe that the ground truth visualizations are in HSV colour space? Try to reason it.

Ans

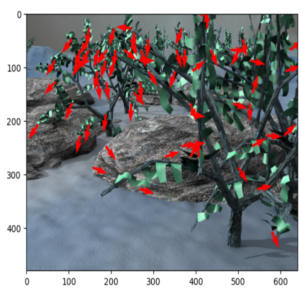
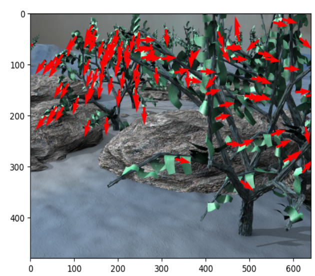
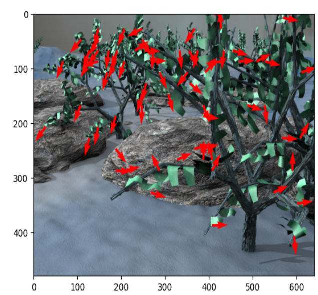
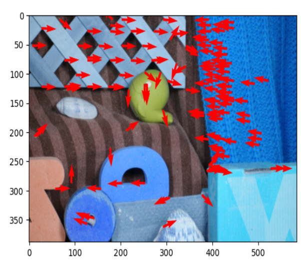
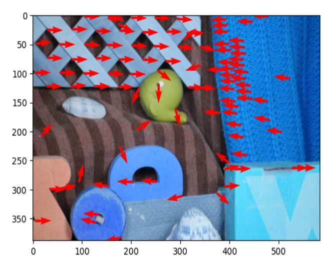
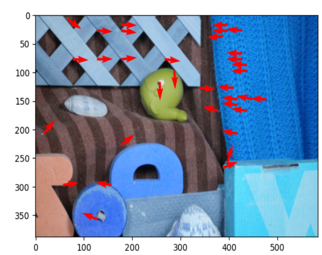
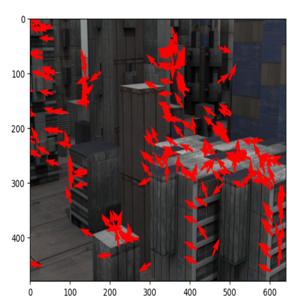
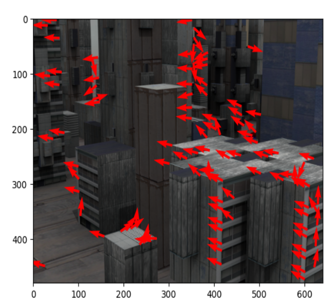
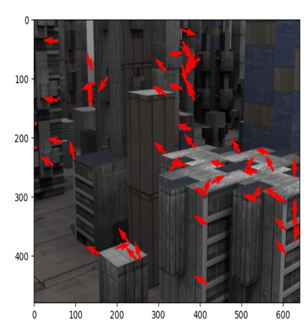
An HSV color model is the most accurate color model as far as the way humans perceive colors. The H stands for Hue (The hue represents the color), S stands for Saturation (The saturation value tells us how much quantity of respective color must be added), and the V stands for value (The value represents the brightness concerning the saturation of the color.).



Here we observe that HSV visualizes the angle (direction) of flow by hue and the distance (magnitude) of flow by value of HSV color representation. So different brightness levels signify which parts of the image are having significant motion and which are having less.
Advantage of using HSV is that small changes in the flow vectors are more easily distinguishable in the HSV color space, compared to the RGB color space, making it easier to interpret the flow field.

Comparison of images and Errors:
All the required images have been added to their respective folders with appropriate names.
Errors corresponding to the respective images have been shown in the code file.
Images are shown in the order:
(i) My implementation   (ii) OpenCV implementation   (iii) Multi-Scale Lucas Kanade

Here showing one image for each class. Rest images are stored in the Result Folder.

			error 3.4074713052613816
			error 91357471.05504923
			error 9.07940591779002

<u>Some Conclusions:</u>

We observed that Error for Grove images is minimum among all three. Although Error is in normal range but for RubberWhale images error is absurdly high. This might be because of some absurd values in the .flo file given as the optical observation is close to what is observed in case of OpenCV implementation. I have shown less number of vectors based on threshold which can be manipulated accordingly.

Comparison of MultiScale LK and Single scale LK:

Since Single scale operates on single scale , It does not perform upto the mark for the case where there is significant variations/ motion in different scale. On the other hand, Multiscale LK handles the case as it performs at different resolution scales.

Compare against part two using:

1. EPE Error Values (only on feature points detected by you)

Ans

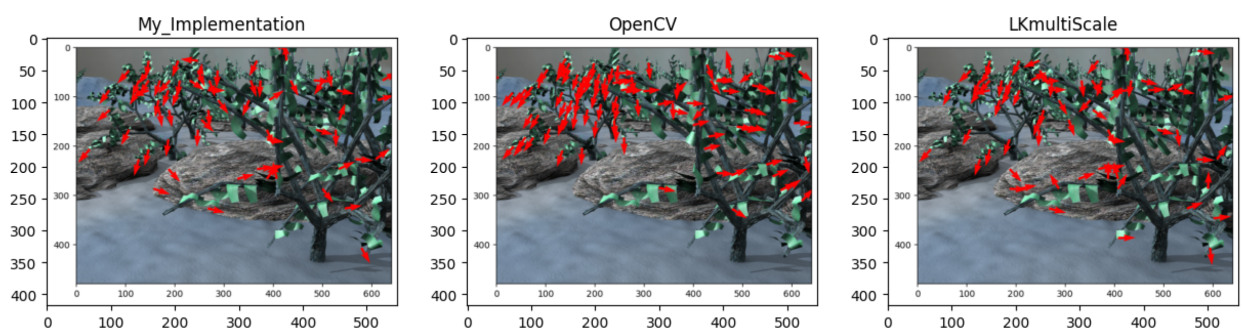
Here we can see error is almost same

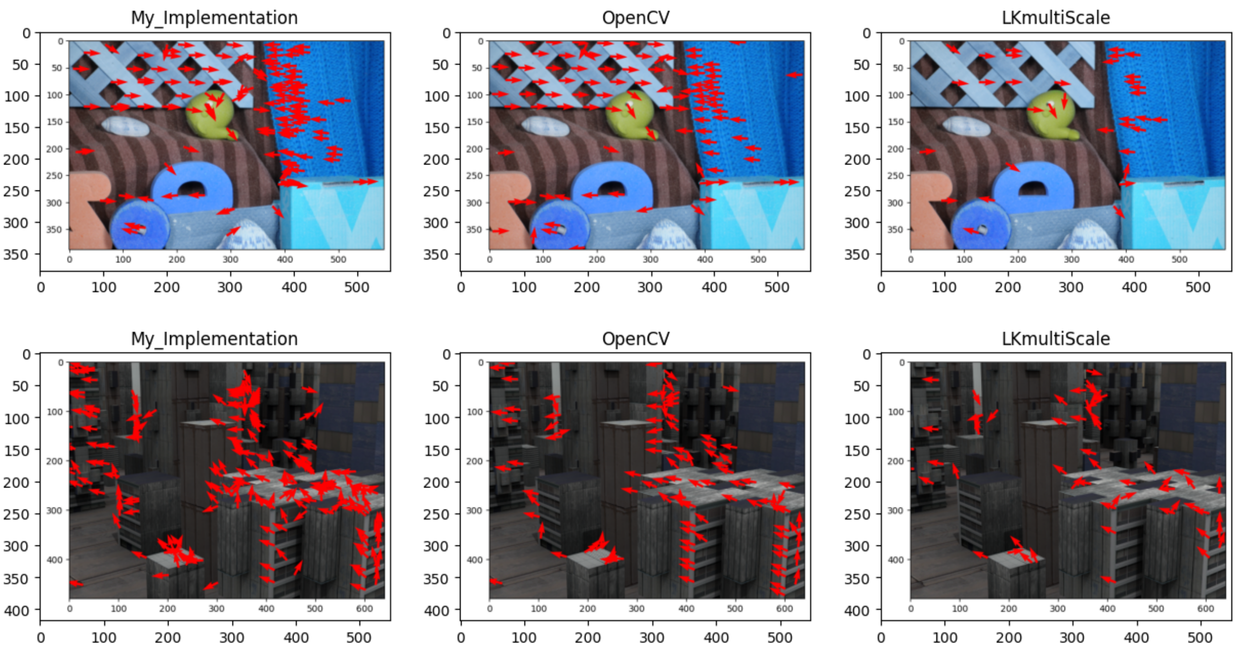
EPE

Image	My Implementation	LK multiscale
Grove	3.407206524292716	3.4074713052613816
RubberWhale	91357471.05513935	91357471.05504923
Urban	9.079247572435973	9.07940591779002

2. Images with the optical flow (from the three image sequences) for single scale LK, Multiscale LK and OpenCV implementation and analyze the results.

For frame 7-8 . Rest can be seen in code file




My_Implementation
OpenCV
LKmultiScale
My_Implementation
OpenCV
LKmultiScale