20171056_Assignment_5

April 19, 2020

```
In [1]: import numpy as np
        import matplotlib.pyplot as plt
        import cv2
        import os
```

1 Optical flow assignment

1.0.1 Overview

This python notebook contains code that computes the following

- Computes optical flow
- Tracks bounding box and good features
- Outputs from the result

1.0.2 Steps to compute optical flow

- Compute image derivatives dx, dy and dt
    - dx - convolution with

$$\begin{bmatrix} -1 & 0 & 1 \end{bmatrix}$$

    - dy - convolution with

$$\begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$$

- dt - image[t] - image[t-1]

- For each pixel calculate optical flow across the filter size using the following equations

$$A = \begin{bmatrix} \sum dx^2 & \sum dx * dy \\ \sum dx * dy & \sum dy^2 \end{bmatrix}$$

$$b = \begin{bmatrix} -\sum dx * dt \\ -\sum dy * dt \end{bmatrix}$$

$$\begin{bmatrix} u \\ v \end{bmatrix} = A^{-1} * b$$

In [2]:
```
'''
Author: Rahul Sajnani

'''
def compute_image_derivative(image):

    '''
    Function to compute image derivative along x and y axis

    Input:
        image - H x W - input image
    Returns:
        list of image derivatives along x and y axis
    '''

    image_x_filter = np.array([[ -1, 0, 1]])

    image_y_filter = np.array([[ -1],
                               [  0],
                               [  1]])

    image_x_derivative = cv2.filter2D(image, -1, image_x_filter)
    image_y_derivative = cv2.filter2D(image, -1, image_y_filter)

    return [image_x_derivative, image_y_derivative]

def compute_optical_flow(image_1, image_2, filter_size):

    '''
    Computes optical flow between two images

    Input:
        image_1 - H x W - input image 1
        image_2 - H x W - input image 2
        filter_size - tuple - filter size

    Returns:
        flow_matrix - H x W x 2 - matrix with flow vectors

    '''

    if (len(image_1.shape) > 1) and (len(image_2.shape) > 1):
        image_1 = cv2.cvtColor(image_1, cv2.COLOR_BGR2GRAY)
        image_2 = cv2.cvtColor(image_2, cv2.COLOR_BGR2GRAY)
```

```
image_1 = normalize_image(image_1)
image_2 = normalize_image(image_2)

image_1_derivative = compute_image_derivative(image_1)
image_2_derivative = compute_image_derivative(image_2)

# dx^2
image_x_derivative_square = image_1_derivative[0] * image_1_derivative[0]

# dy^2
image_y_derivative_square = image_1_derivative[1] * image_1_derivative[1]

# dx*dy
image_xy_derivative = image_1_derivative[0] * image_1_derivative[1]

# dt
image_t_derivative = image_2 - image_1

image_xt_derivative = image_1_derivative[0] * image_t_derivative
image_yt_derivative = image_1_derivative[1] * image_t_derivative

summation_filter = np.ones(filter_size)


# computing summation dx^2, dy^2, dx*dt, dy*dt, dx*dy
image_xt_derivative_summation = cv2.filter2D(image_xt_derivative, -1, summation_filt
image_yt_derivative_summation = cv2.filter2D(image_yt_derivative, -1, summation_filt
image_x_derivative_square_summation = cv2.filter2D(image_x_derivative_square, -1, su
image_y_derivative_square_summation = cv2.filter2D(image_y_derivative_square, -1, su
image_xy_derivative_summation = cv2.filter2D(image_xy_derivative, -1, summation_filt

flow_matrix = np.zeros((image_1.shape[0], image_1.shape[1], 2))

for i in range(image_1.shape[0]):

    for j in range(image_1.shape[1]):

        # computing matrix
        optical_flow_mat = np.array([[image_x_derivative_square_summation[i, j], ima
                                     [image_xy_derivative_summation[i, j], image_y_de
        # print(optical_flow_mat.shape)
        b = -np.array([[image_xt_derivative_summation[i, j]], [image_yt_derivative_s

        flow_vector = np.linalg.pinv(optical_flow_mat) @ b

        factor = np.sqrt(flow_vector[0]**2 + flow_vector[1]**2)
        if factor > 0.3:
```

```
                flow_matrix[i, j, :] = flow_vector.T

            # print(flow_vector)
        # print(i)


    print('Optical flow computed')
    print(np.max(flow_matrix))
    return flow_matrix

def plot_flow_image(image, flow_matrix):
    '''
    Plot flow vectors on image

    '''
    plt.imshow(image, 'gray')
    for i in range(0, flow_matrix.shape[0], 30):
        for j in range(0, flow_matrix.shape[1], 30):
            plt.quiver(j, i, flow_matrix[i, j, 0], flow_matrix[i, j, 1], scale = 10)

def normalize_image(image):
    '''
    Function to normalize image
    '''
    image = (image - np.mean(image)) /255

    return image

def get_good_features(image_1):
    '''
    Extract good features from image
    '''

    if len(image_1.shape) > 1:
        image_1_gray = cv2.cvtColor(image_1, cv2.COLOR_BGR2GRAY)
    else:
        image_1_gray = image_1

    corners = cv2.goodFeaturesToTrack(image_1_gray, 200, 0.01, 10)
    corners = np.int0(corners)
    corners = np.reshape(corners, (-1, 2))

    return corners

def segmentation(image, flow_matrix):
    '''
    Get segmentation of moving objects using flow matrix
    '''
```

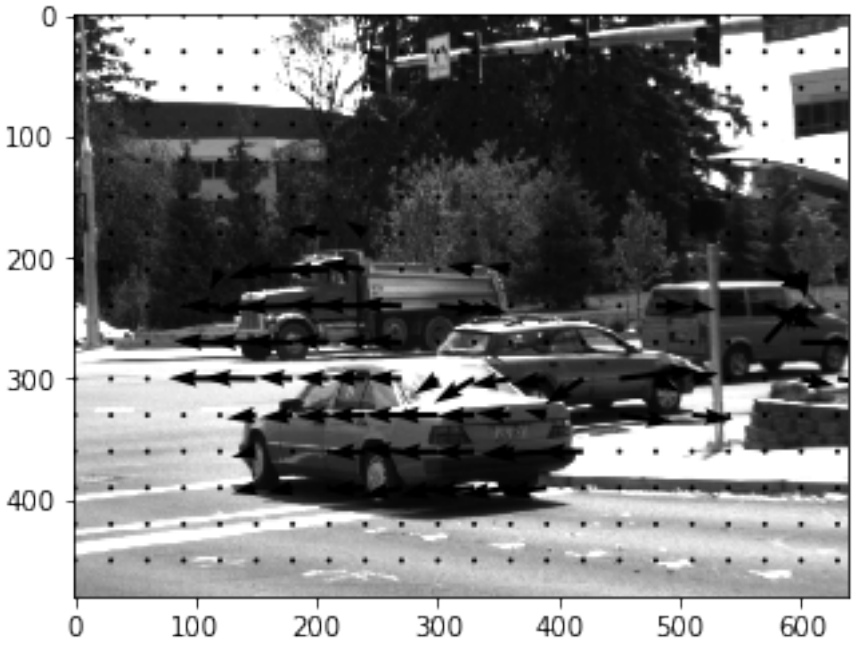
```
    segmentation_mask = np.zeros((image.shape[0], image.shape[1]))

    for i in range(image.shape[0]):

        for j in range(image.shape[1]):

            segmentation_mask[i, j] = np.sqrt(flow_matrix[i, j, 0]**2 + flow_matrix[i, j

    plt.imshow(segmentation_mask, 'gray')
    plt.show()

def SaveImages(directoryName, list_images):
    '''
    function to convert video to images
    Input:
        directoryName - name of direcotry to output images
        list_images - list - list of images
    Output:
        none
    '''
    if not os.path.exists(directoryName):
        os.makedirs(directoryName)


    print('saving images')
    for i in range (len(list_images)):
        imageName = '%06d.jpg' % i
        imagePath = directoryName + '/' + imageName
        cv2.imwrite(imagePath, list_images[i])
    print('Save complete. Output saved in ' + directoryName)

def Image2Vid(dirName, fps, outputDir, vidName):

    '''
    function to conver images to video with given fps
    Input:
        dirName - directory name with images
        fps - output fps
        outputDir - output directory name to save video
    Output:
        none
    '''


    imageArray = []
    files = [images for images in os.listdir(dirName) if os.path.isfile(os.path.join(dir
    files.sort()
```

```
    if not os.path.exists(outputDir):
        os.makedirs(outputDir)

    for i in range(len(files)):
        fileName = dirName + '/'+ files[i]
        image = cv2.imread(fileName)
        imageArray.append(image)

    height, width, layers = imageArray[0].shape
    size = (width, height)

    video = cv2.VideoWriter(outputDir + '/' + vidName,cv2.VideoWriter_fourcc(*'DIVX'), f
    for i in range(len(imageArray)):
        video.write(imageArray[i])
    video.release()
    print('Video path ' + outputDir + '/' + vidName)


def bounding_box_tracking(directory, bbox = None):
    '''
    Function to move bounding box by the optical flow obtained from the good features wi
    '''

    imageArray = []
    image_array_output = []

    files = [images for images in os.listdir(directory)]
    files.sort()

    for i in range(len(files)):
        print(i)
        fileName = directory + '/'+ files[i]
        image = cv2.imread(fileName)
        imageArray.append(image)



    if bbox is None:
        print('Draw bounding box')
        r = cv2.selectROI(imageArray[0])
        bbox = [r[0], r[1], r[0] + r[2], r[1] + r[3]]
        bbox = bbox

    cv2.destroyAllWindows()
    mult_factor = 3
    running_bbox = bbox
    filter_size = ( 31, 31)
    for i in range(len(imageArray) - 1):
```

```
            bounding_box_shift_x = 0
            bounding_box_shift_y = 0
            # compute flow
            flow_matrix = compute_optical_flow(imageArray[i], imageArray[i + 1], filter_size
            corners = get_good_features(imageArray[i])

            corners_in_box = np.logical_and(np.logical_and(corners[:, 0] > running_bbox[0],
                                                           corners[:, 0] < running_bbox[2]),
                                            np.logical_and(corners[:, 1] > running_bbox[1],
                                                           corners[:, 1] < running_bbox[3]))

            corners_in_box = corners[corners_in_box, :]

            if corners_in_box.shape[0] > 0:

                total_points = corners_in_box.shape[0]

                for points in corners_in_box:
                    bounding_box_shift_x += mult_factor*flow_matrix[points[1], points[0], 0]
                    bounding_box_shift_y += mult_factor*flow_matrix[points[1], points[0], 1]

            print(running_bbox)
            running_bbox = [int(running_bbox[0] + bounding_box_shift_x),
                            int(running_bbox[1] + bounding_box_shift_y),
                            int(running_bbox[2] + bounding_box_shift_x),
                            int(running_bbox[3] + bounding_box_shift_y)]

            print(running_bbox)

            next_image = imageArray[i + 1]
            cv2.rectangle(next_image, (int(running_bbox[0]), int(running_bbox[1])),
              (int(running_bbox[2]), int(running_bbox[3])), (0, 255, 0), 2)
            plt.imshow(next_image)
            plt.show()
            image_array_output.append(next_image)

        folder = directory.split('/')[-1]
        directory_output = './outputs/' + folder
        SaveImages(directory_output, image_array_output)
        Image2Vid(directory_output, 8, directory_output + '/output', 'video.mp4')



In [3]: if __name__ == '__main__':

            dataset = './eval-data-gray'
```

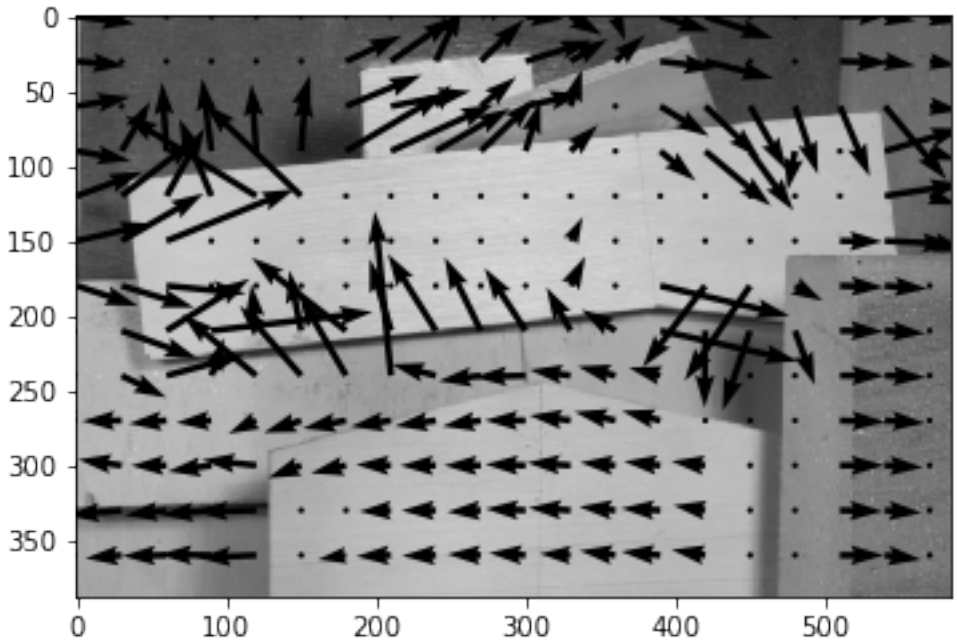
```
directory = '/Dumptruck'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
1.8176778334267094
```



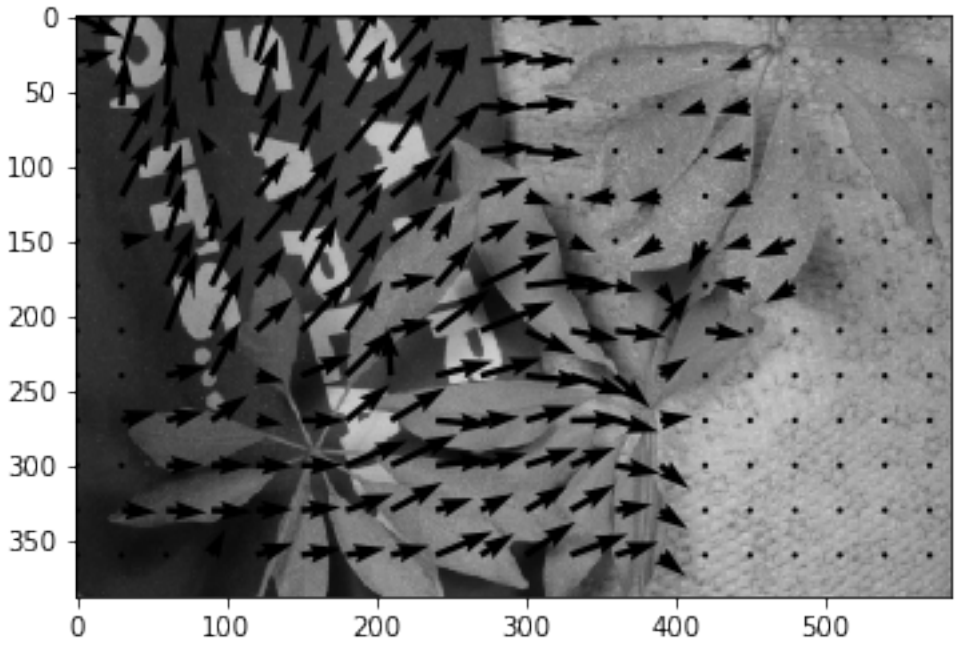
In [4]:
```
directory = '/Wooden'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
5.765109935609735
```



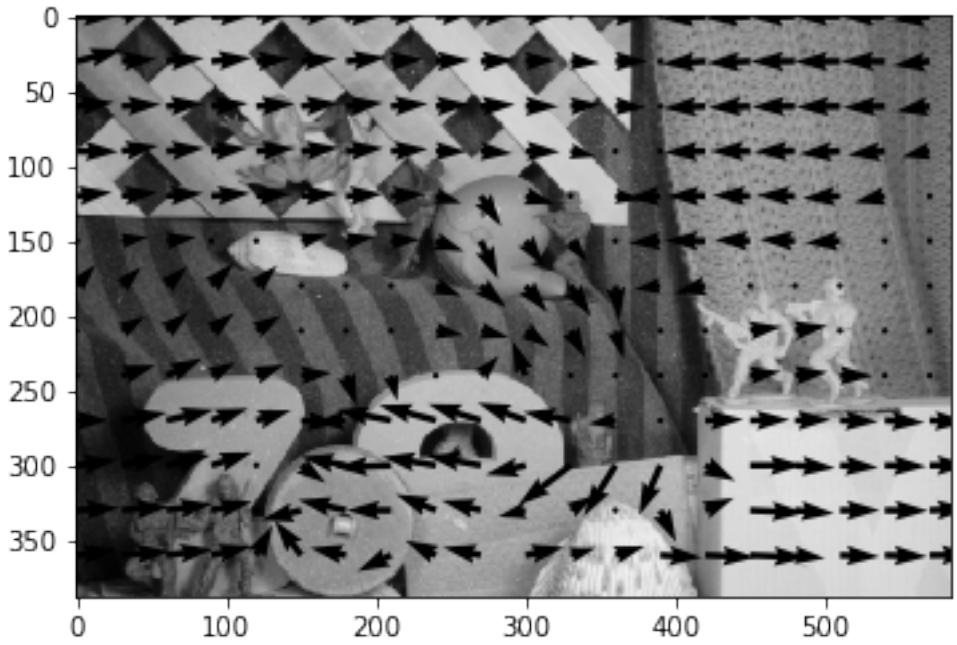
In [5]:
```
directory = '/Schefflera'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
1.3436528180770413
```



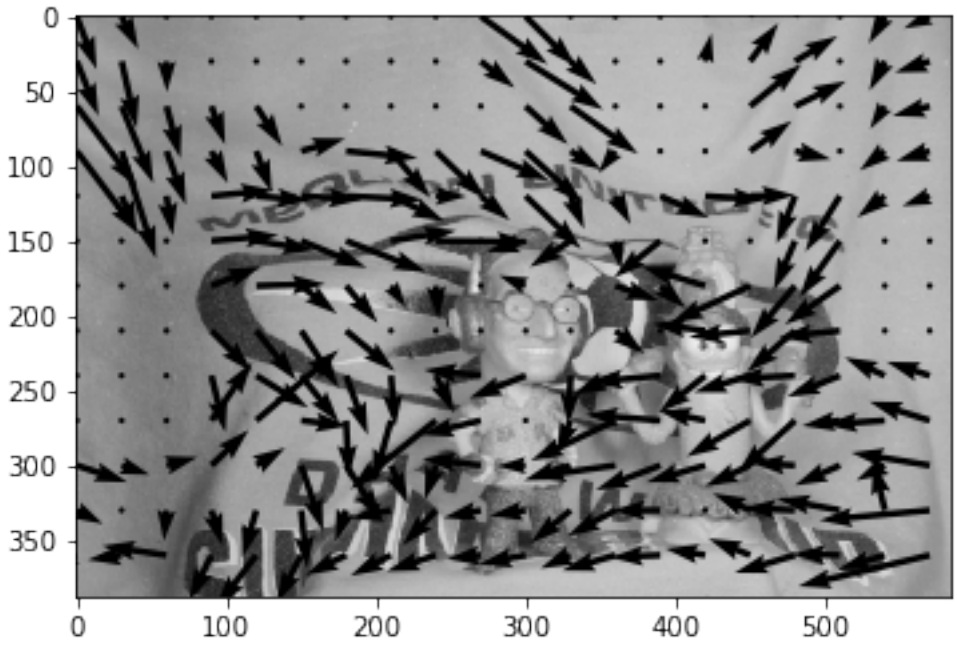
In [6]:
```
directory = '/Army'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
0.8440589903756118
```



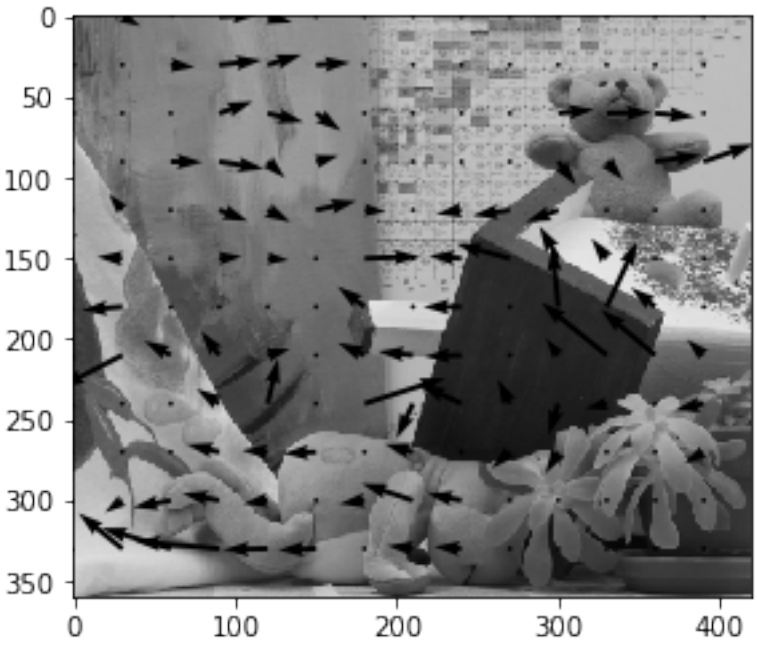
In [7]:
```
directory = '/Mequon'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
1.5299213790854143
```



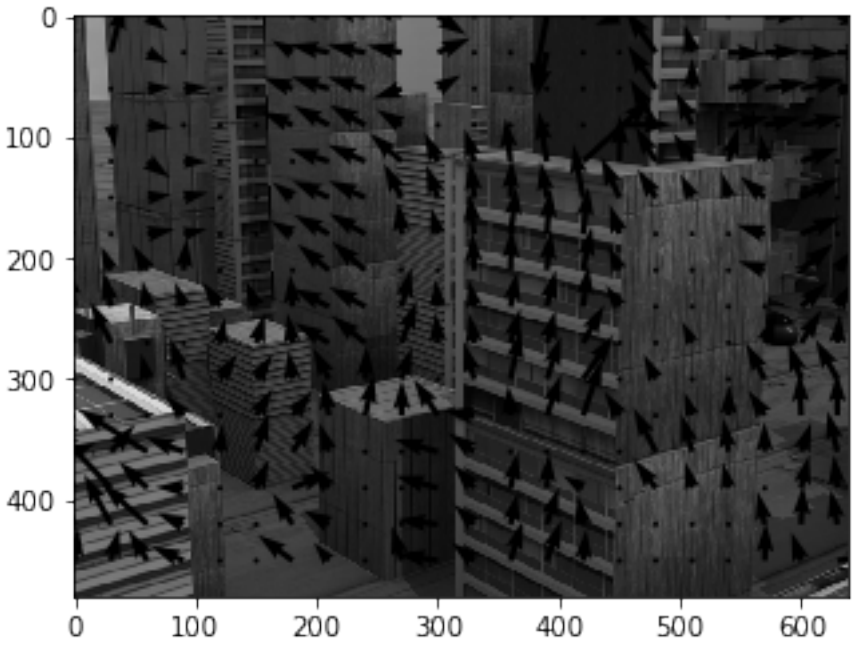
In [8]:
```
directory = '/Teddy'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
2.2360458885028005
```



In [9]:
```
directory = '/Urban'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
```

```
Optical flow computed
2.6626510680615745
```

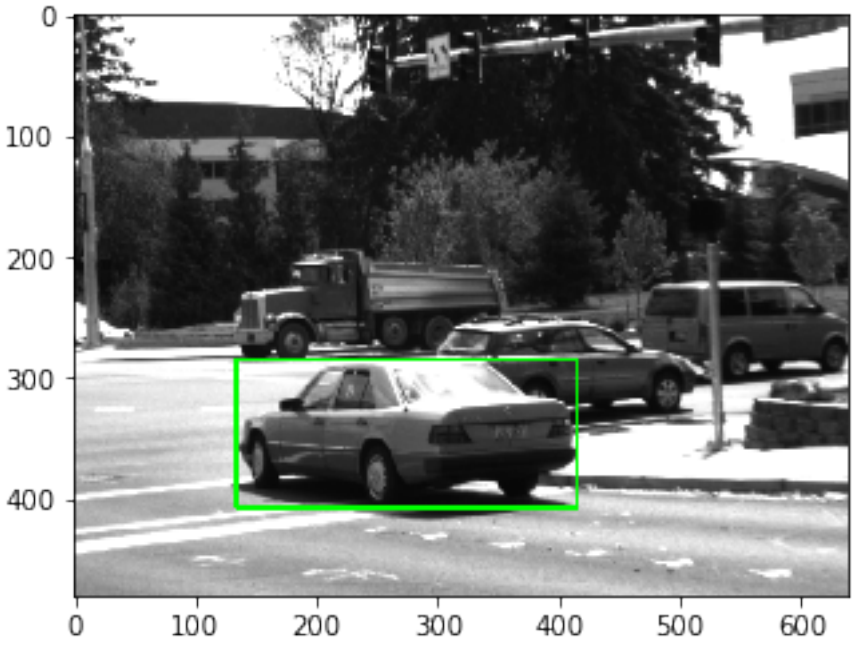


In [10]:
```
dataset_complete = './eval-data-gray-complete'
directory = '/Dumptruck'
bbox = [119, 275, 460, 414]
bounding_box_tracking(dataset_complete + directory)
```

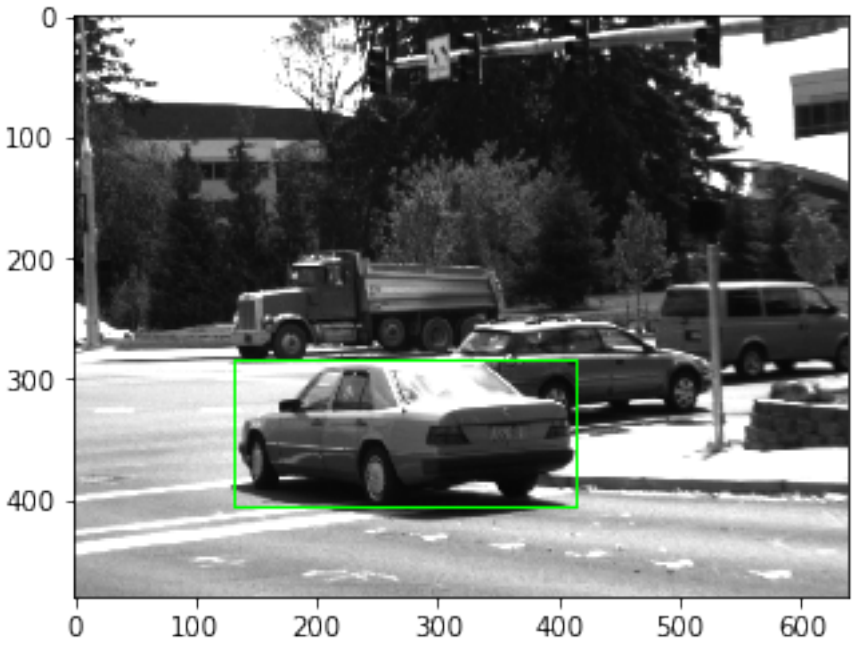
```
0
1
2
3
4
5
6
7
Draw bounding box
Optical flow computed
2.8738112414310057
[138, 288, 420, 410]
[136, 287, 418, 409]
```


```
Optical flow computed
2.2952603664055116
[136, 287, 418, 409]
[135, 286, 417, 408]
```

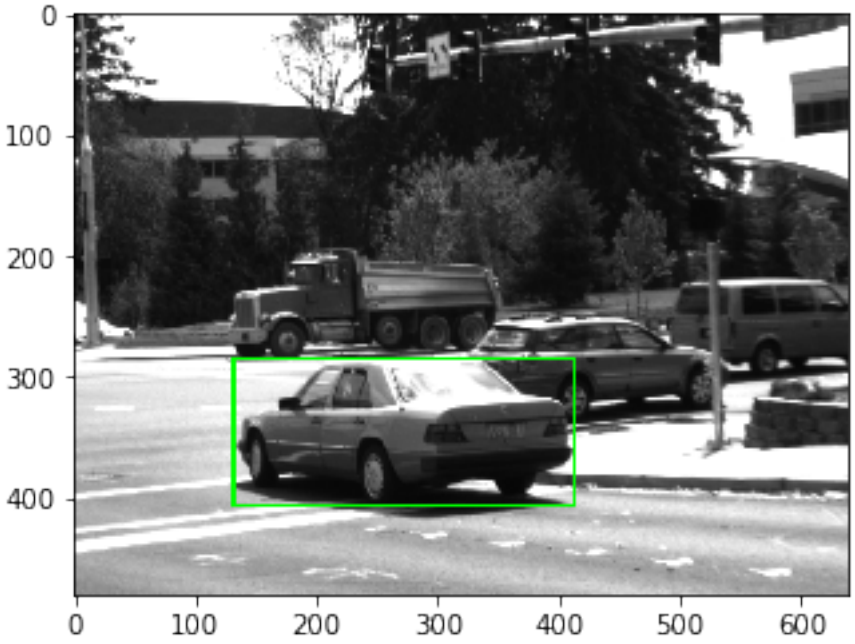
```
Optical flow computed
1.994550463940301
[135, 286, 417, 408]
[134, 285, 416, 407]
```



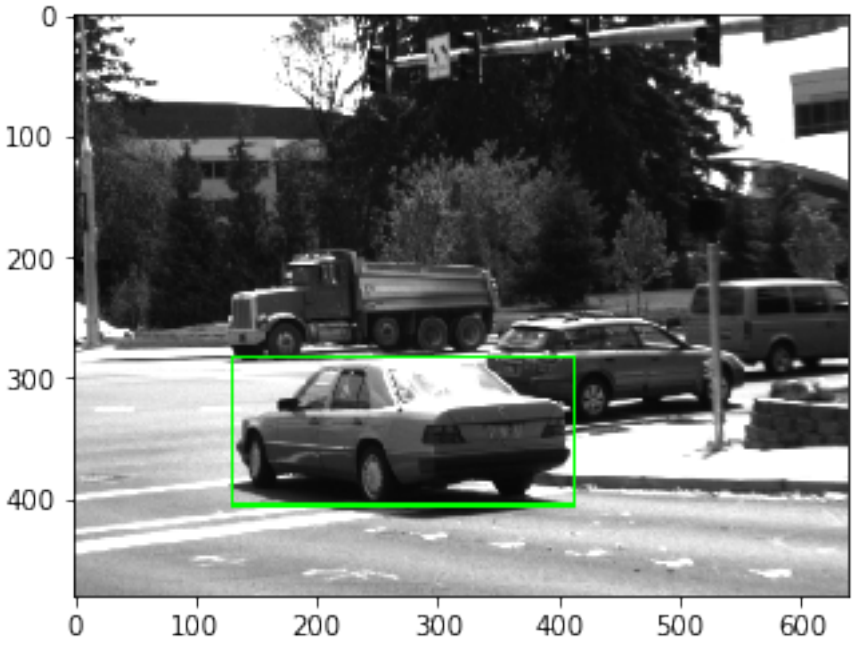

```
Optical flow computed
2.3441372601900685
[134, 285, 416, 407]
[133, 284, 415, 406]
```



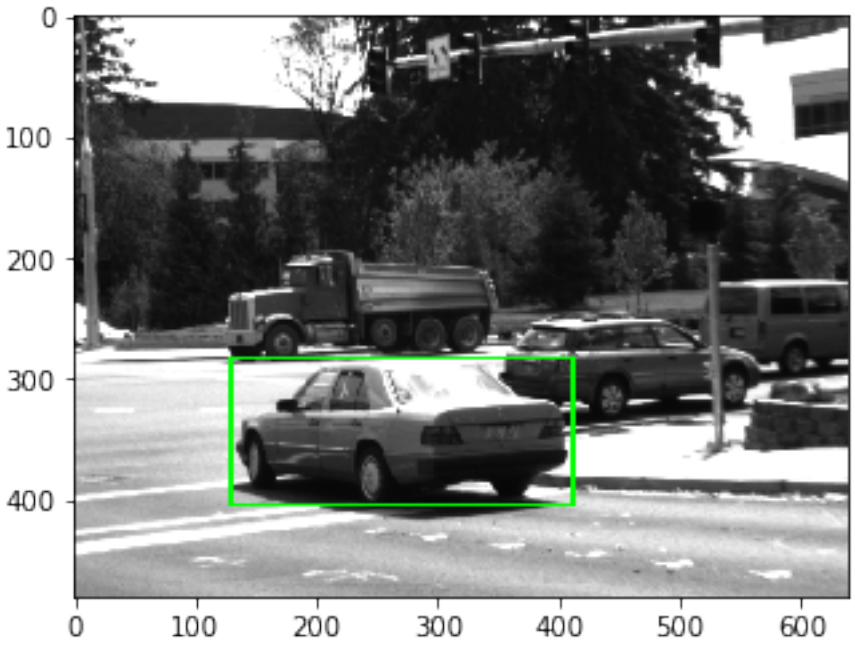

```
Optical flow computed
2.0437202319965615
[133, 284, 415, 406]
[132, 284, 414, 406]
```



```
Optical flow computed
4.30436298564635
[132, 284, 414, 406]
[131, 283, 413, 405]
```




```
Optical flow computed
2.650815060523958
[131, 283, 413, 405]
[130, 282, 412, 404]
```



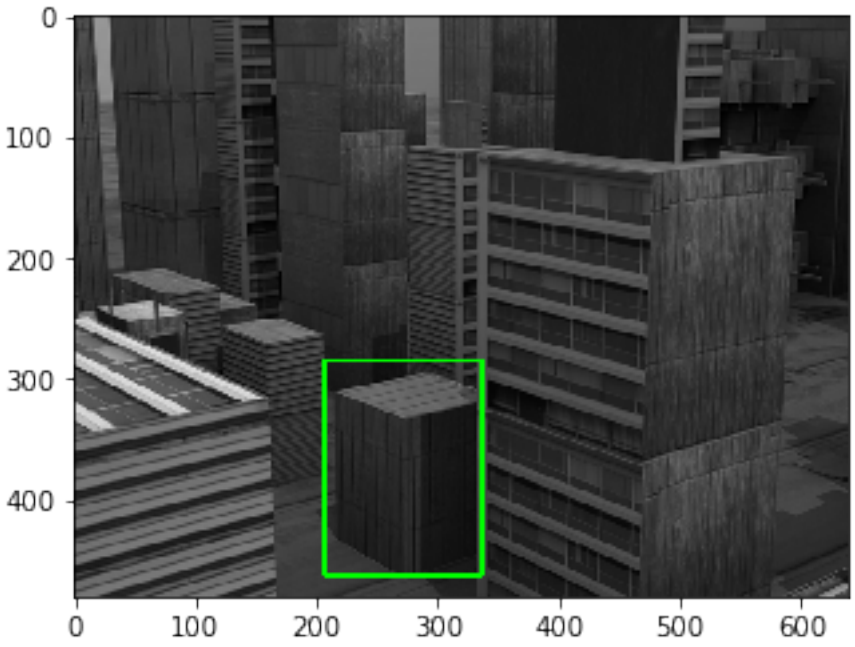

```
saving images
Save complete. Output saved in ./outputs/Dumptruck
Video path ./outputs/Dumptruck/output/video.mp4
```

Case when moving camera

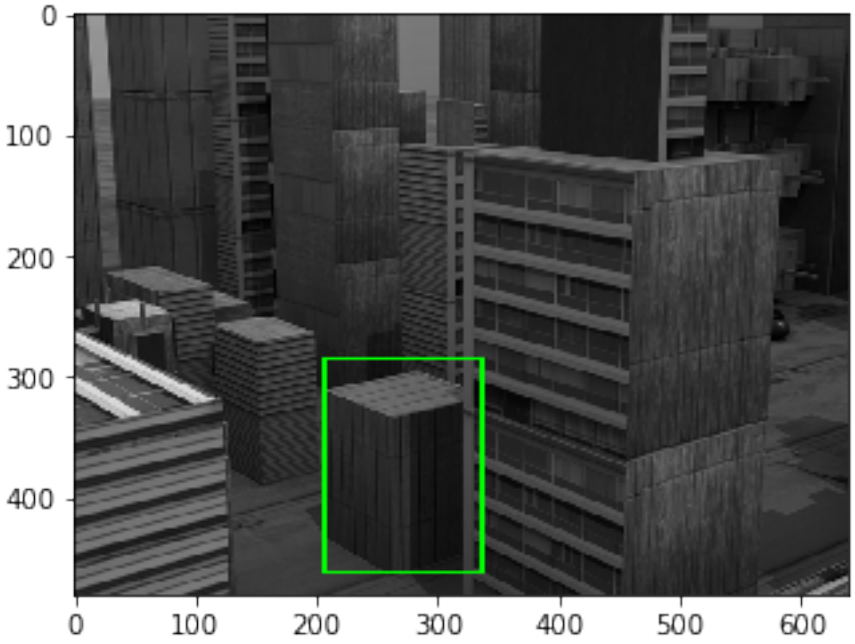
During camera motion the optical flow does not perform very well for large motion

```
In [11]:     dataset_complete = './eval-data-gray-complete'
             directory = '/Urban'
             bbox = [208, 284, 338, 461]
             bounding_box_tracking(dataset_complete + directory, bbox)
```

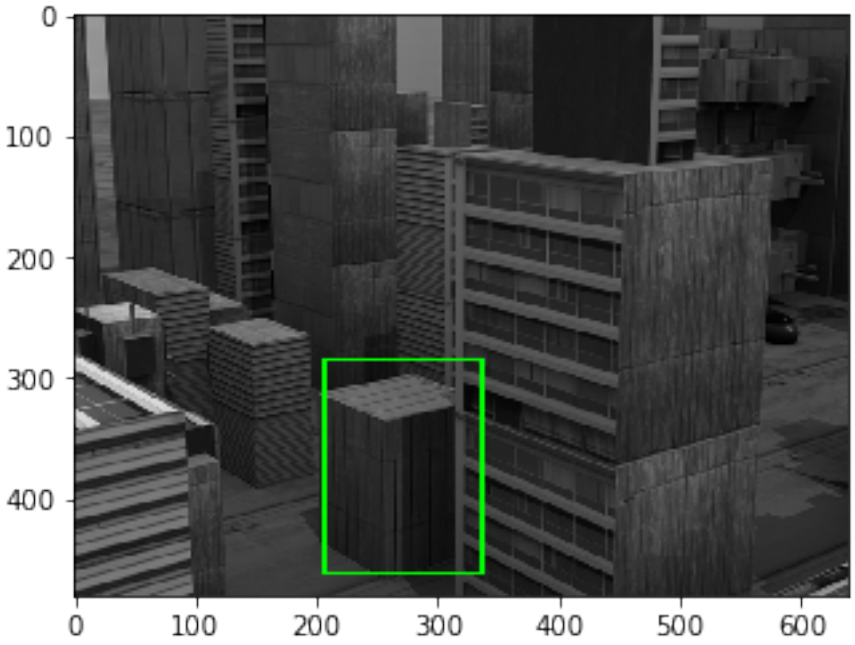
```
0
1
2
3
4
5
6
7
Optical flow computed
7.041625519088246
[208, 284, 338, 461]
[207, 285, 337, 462]
```



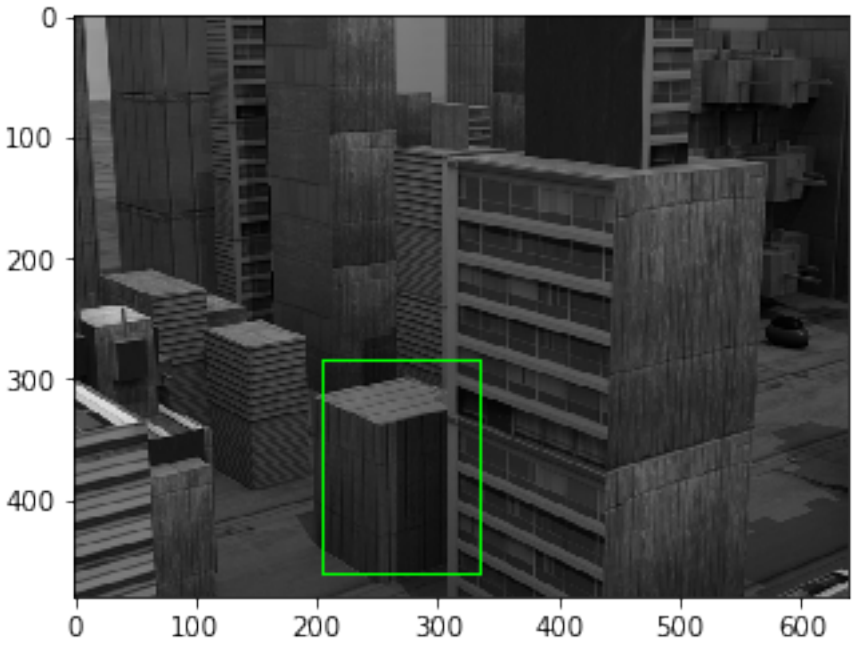

```
Optical flow computed
5.182976615561201
[207, 285, 337, 462]
[207, 284, 337, 461]
```



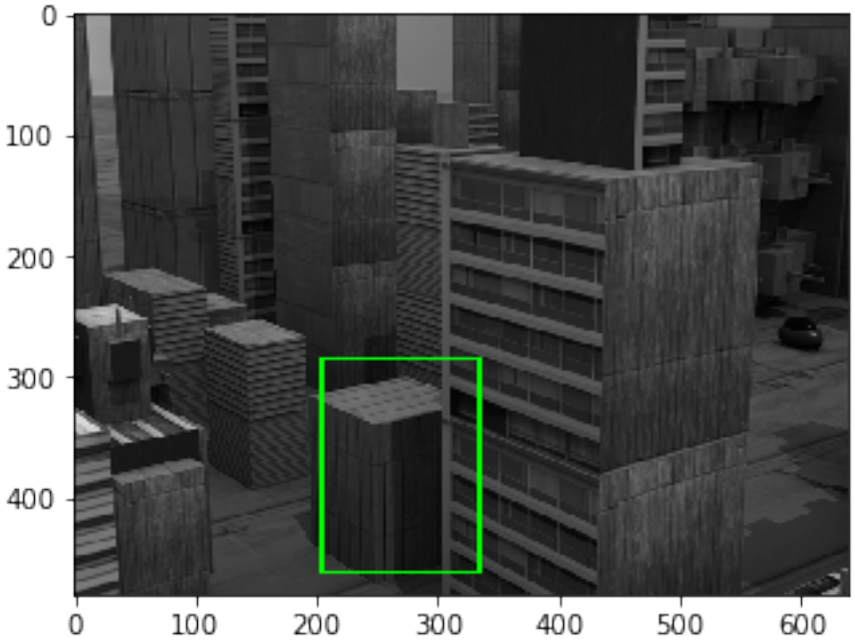
```
Optical flow computed
5.609495922825985
[207, 284, 337, 461]
[207, 284, 337, 461]
```



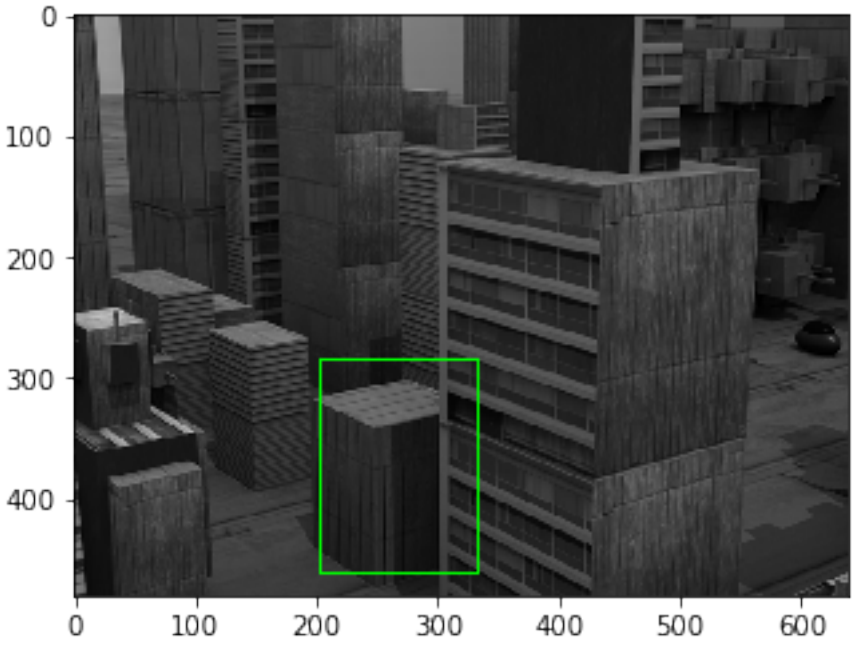

```
Optical flow computed
3.6354003023569557
[207, 284, 337, 461]
[206, 284, 336, 461]
```



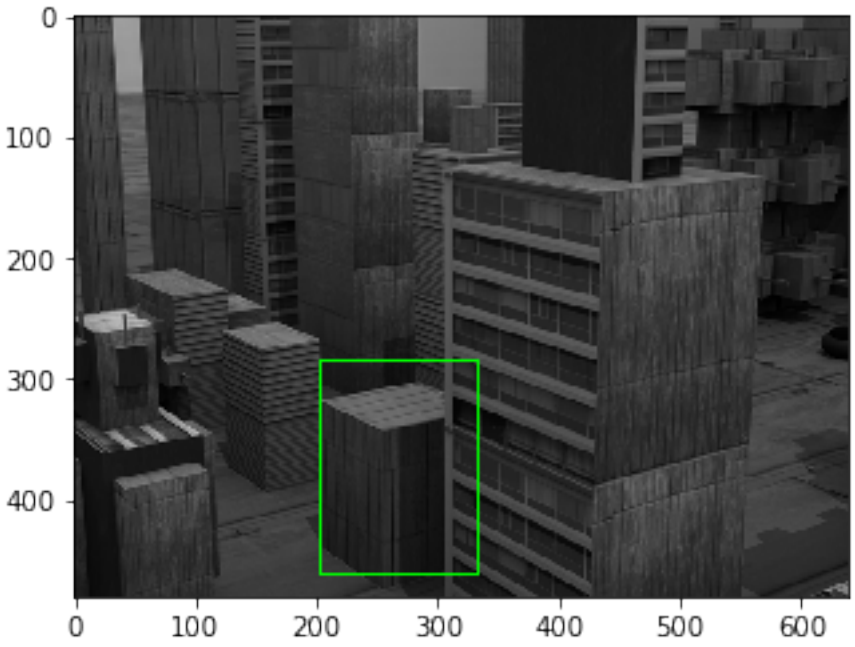

```
Optical flow computed
4.771851684058273
[206, 284, 336, 461]
[205, 284, 335, 461]
```



```
Optical flow computed
7.198882837905978
[205, 284, 335, 461]
[204, 284, 334, 461]
```



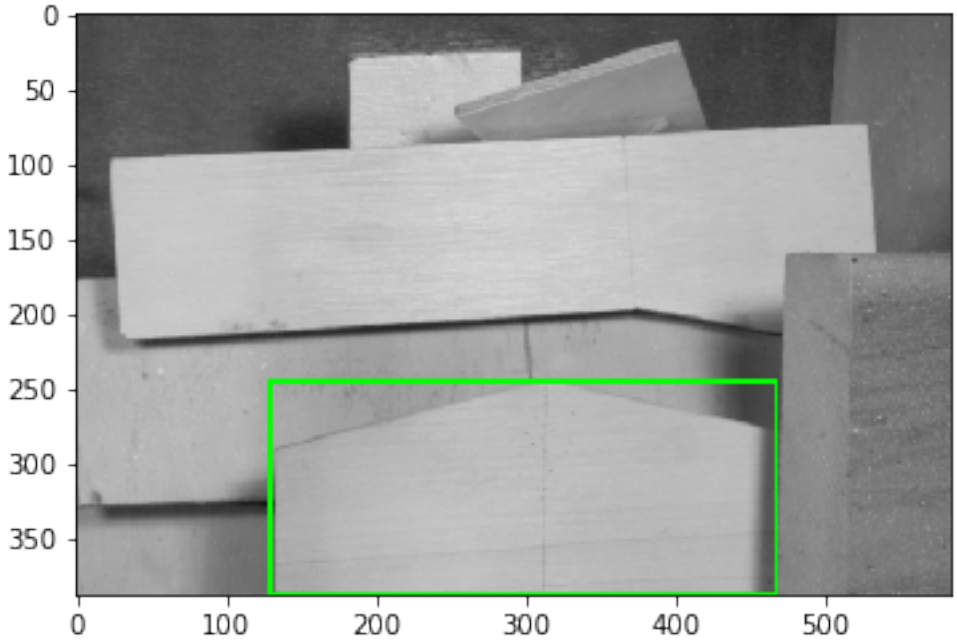

```
Optical flow computed
9.718489130091623
[204, 284, 334, 461]
[204, 284, 334, 461]
```



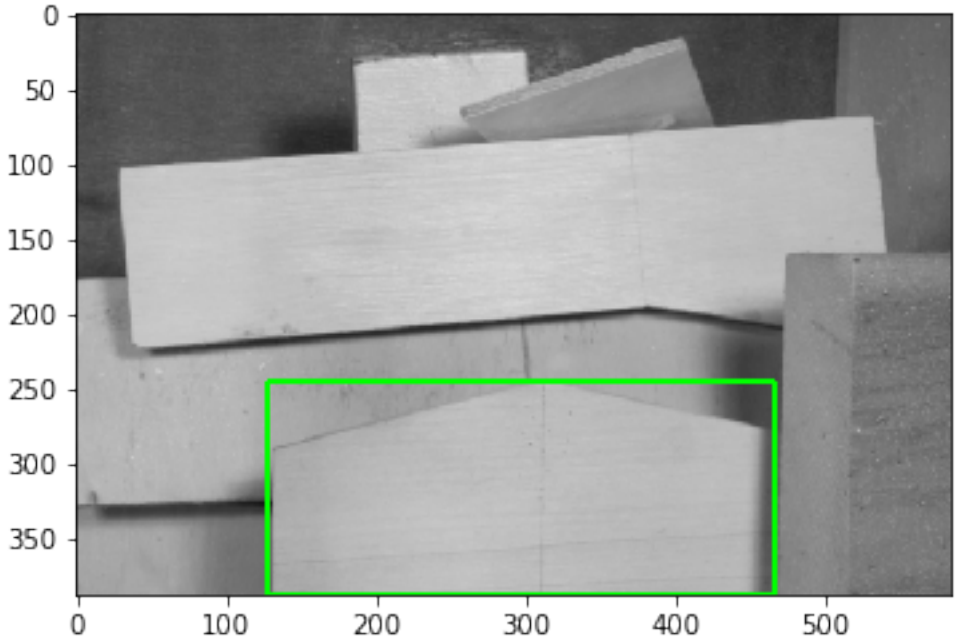

```
saving images
Save complete. Output saved in ./outputs/Urban
Video path ./outputs/Urban/output/video.mp4
```

```
In [12]:    dataset_complete = './eval-data-gray-complete'
            directory = '/Wooden'
            bbox = [208, 284, 338, 461]
            bounding_box_tracking(dataset_complete + directory)
```

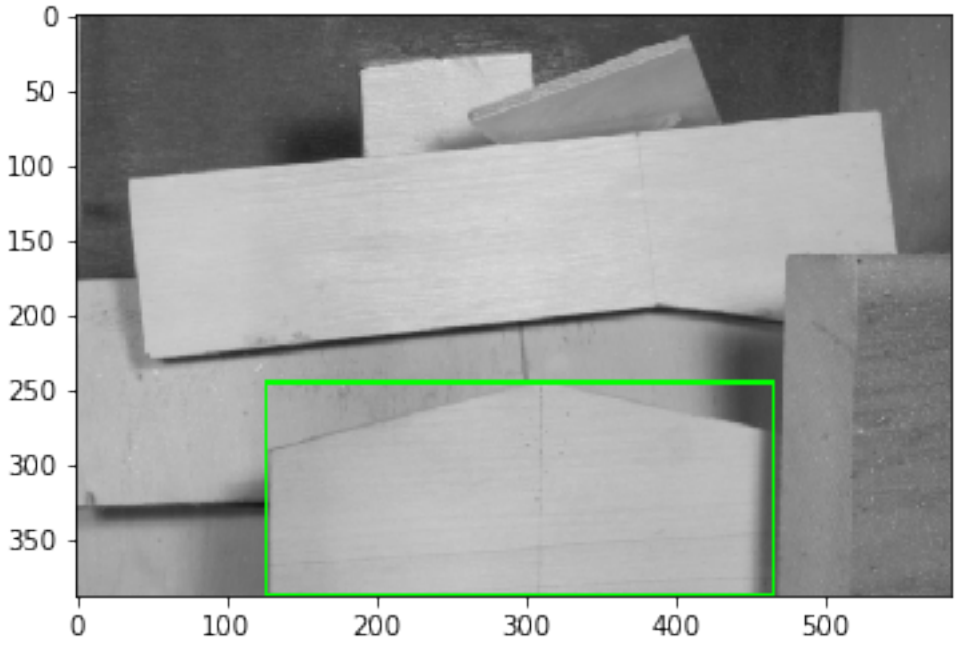
```
0
1
2
3
4
5
6
7
Draw bounding box
Optical flow computed
8.858538359497805
[131, 245, 469, 387]
[129, 245, 467, 387]
```



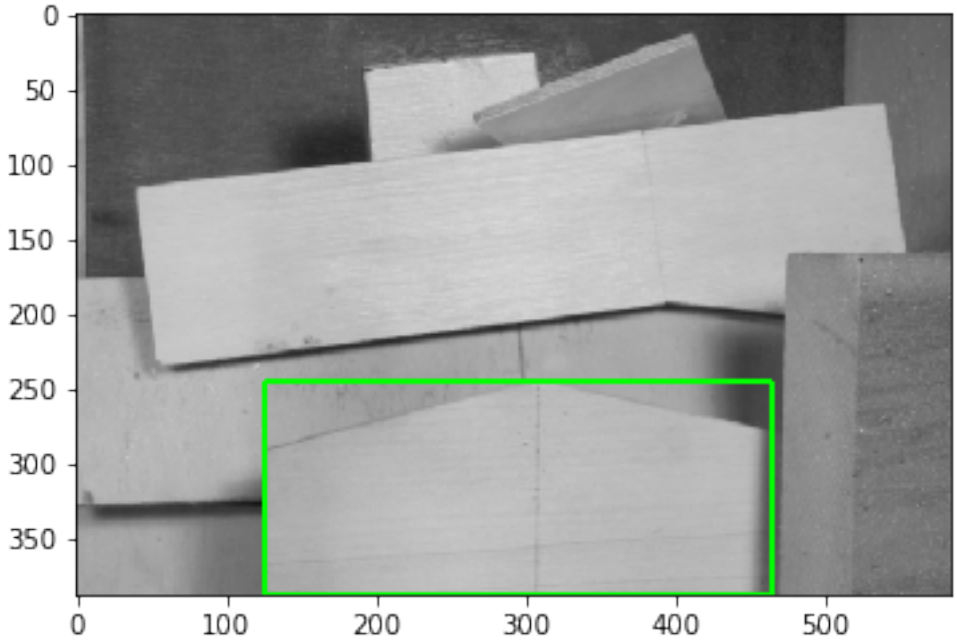

```
Optical flow computed
10.651547220163856
[129, 245, 467, 387]
[128, 245, 466, 387]
```



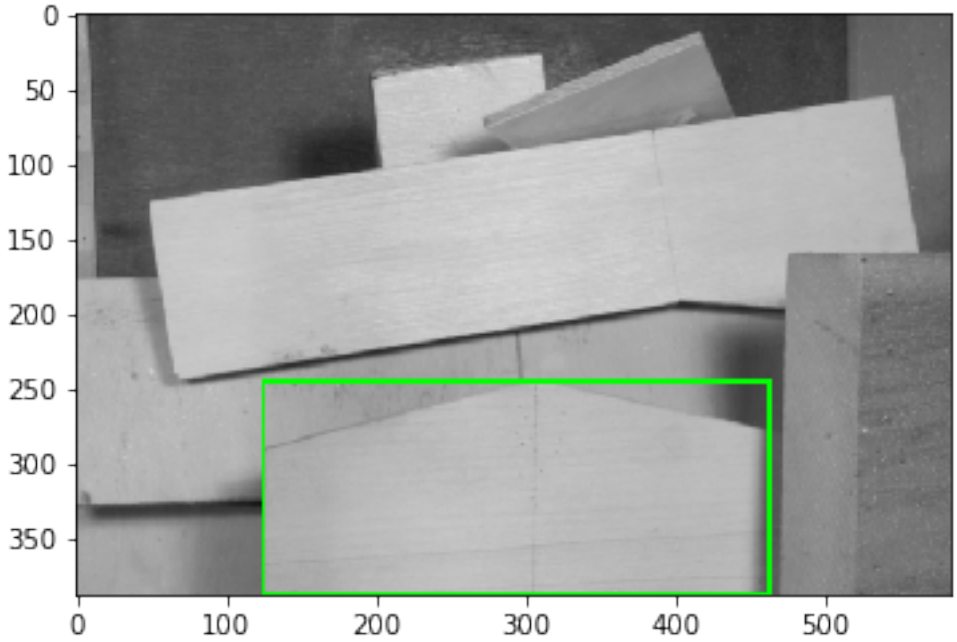
```
Optical flow computed
9.651471870572792
[128, 245, 466, 387]
[127, 245, 465, 387]
```



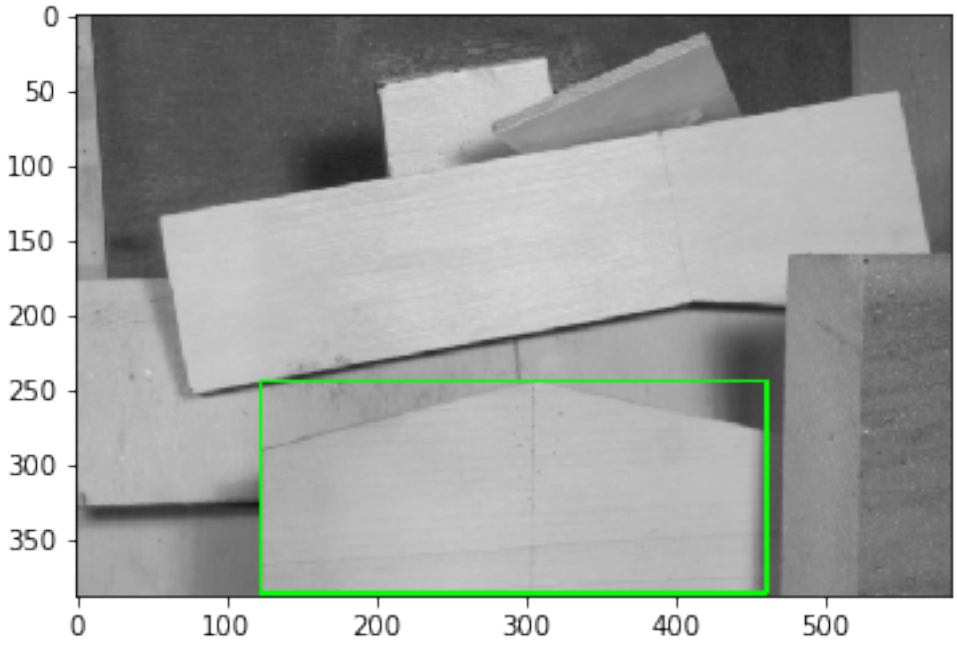

```
Optical flow computed
7.935027316423763
[127, 245, 465, 387]
[126, 245, 464, 387]
```



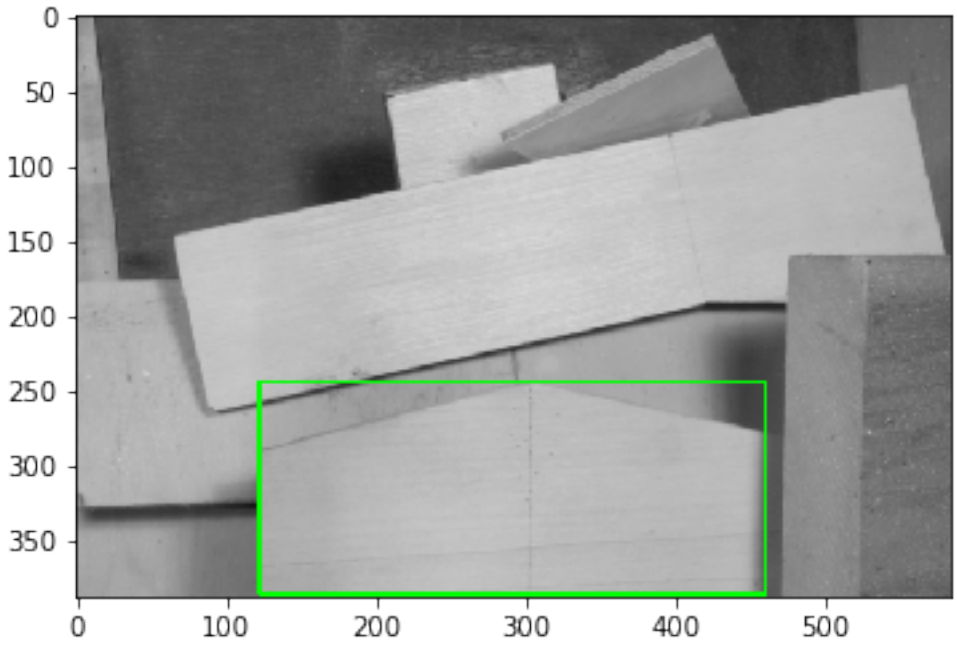

```
Optical flow computed
10.923767035684236
[126, 245, 464, 387]
[125, 245, 463, 387]
```



```
Optical flow computed
8.006281727520413
[125, 245, 463, 387]
[123, 244, 461, 386]
```



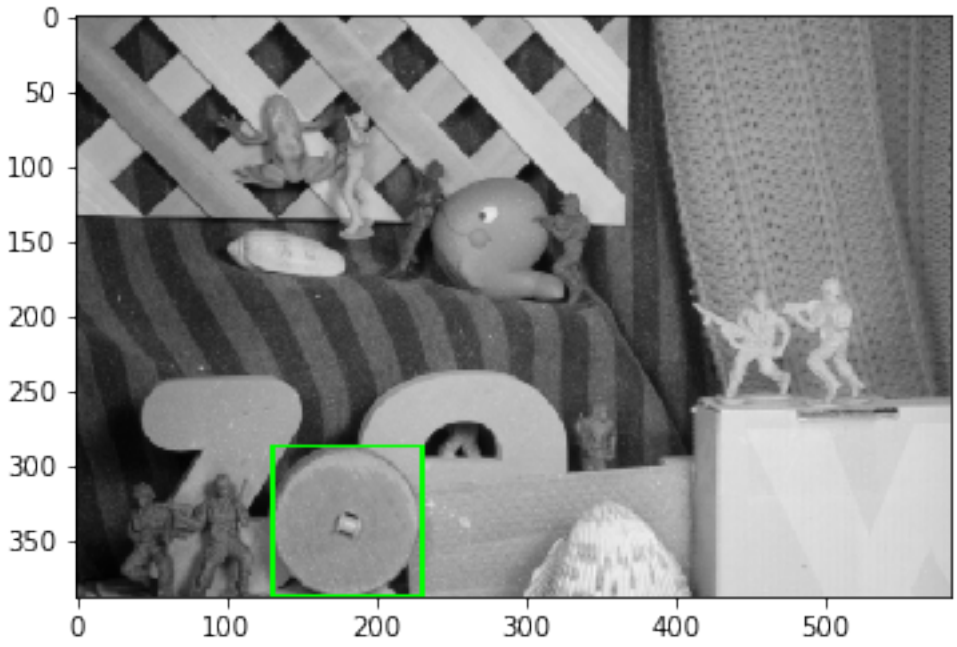

```
Optical flow computed
10.057297069740102
[123, 244, 461, 386]
[122, 244, 460, 386]
```



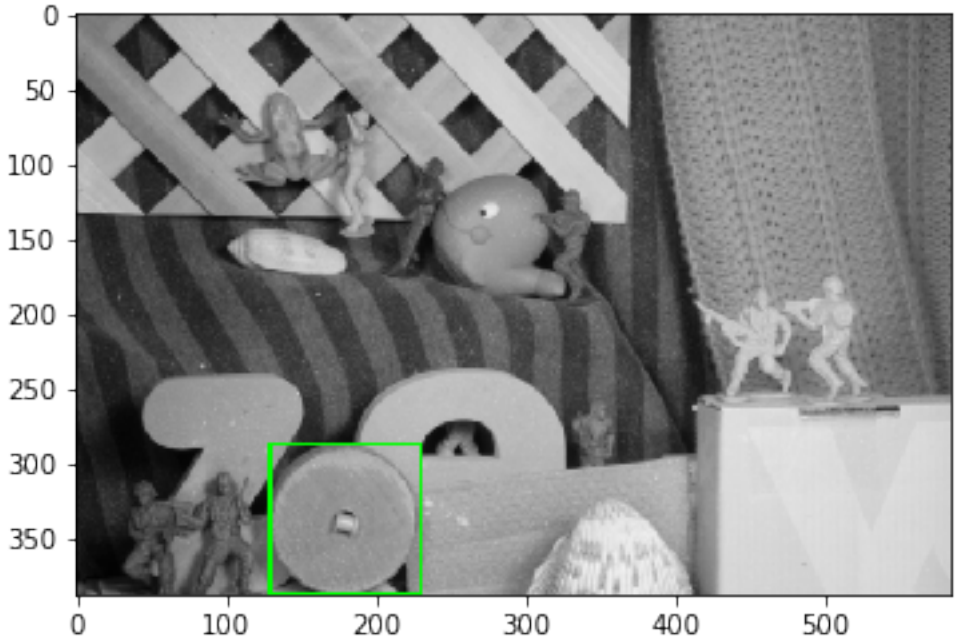

```
saving images
Save complete. Output saved in ./outputs/Wooden
Video path ./outputs/Wooden/output/video.mp4
```

```
In [13]:     dataset_complete = './eval-data-gray-complete'
             directory = '/Army'
             bbox = [208, 284, 338, 461]
             bounding_box_tracking(dataset_complete + directory)
```

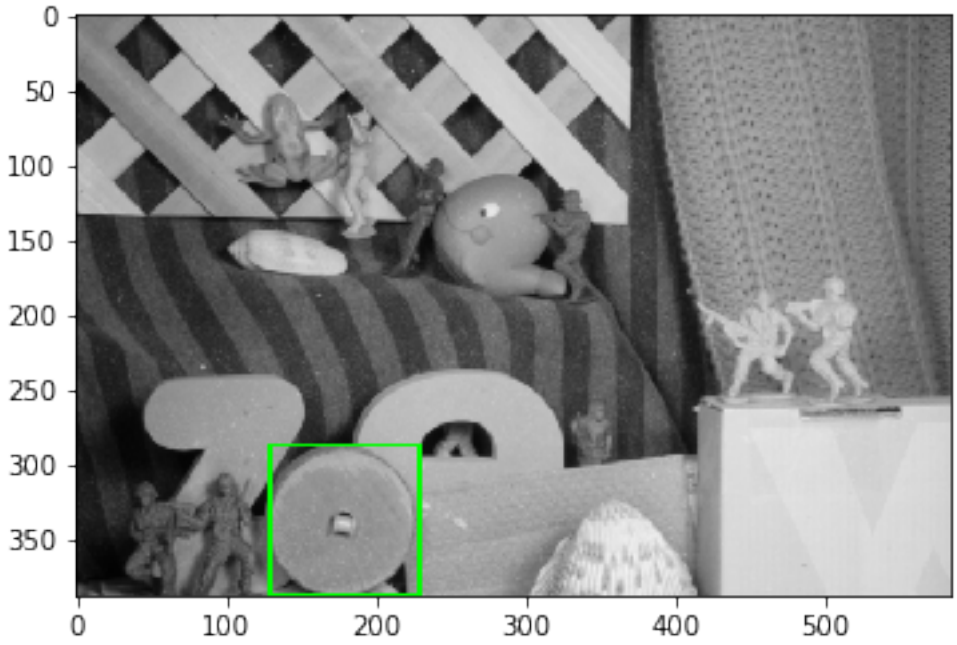
```
0
1
2
3
4
5
6
7
Draw bounding box
Optical flow computed
0.8184656705512934
[133, 287, 233, 387]
[131, 287, 231, 387]
```



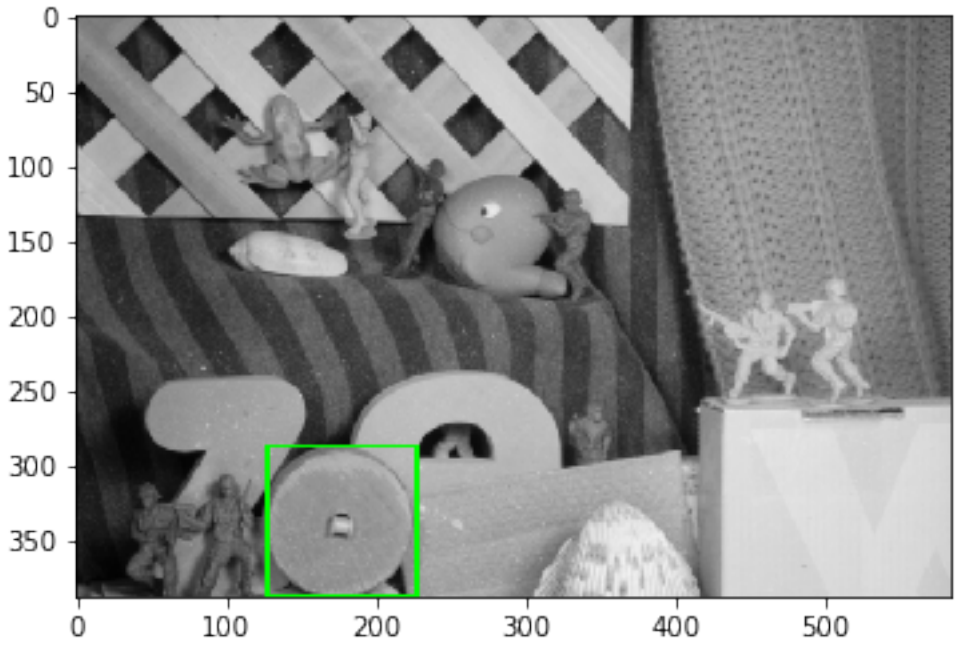

```
Optical flow computed
0.7976839057900222
[131, 287, 231, 387]
[130, 287, 230, 387]
```



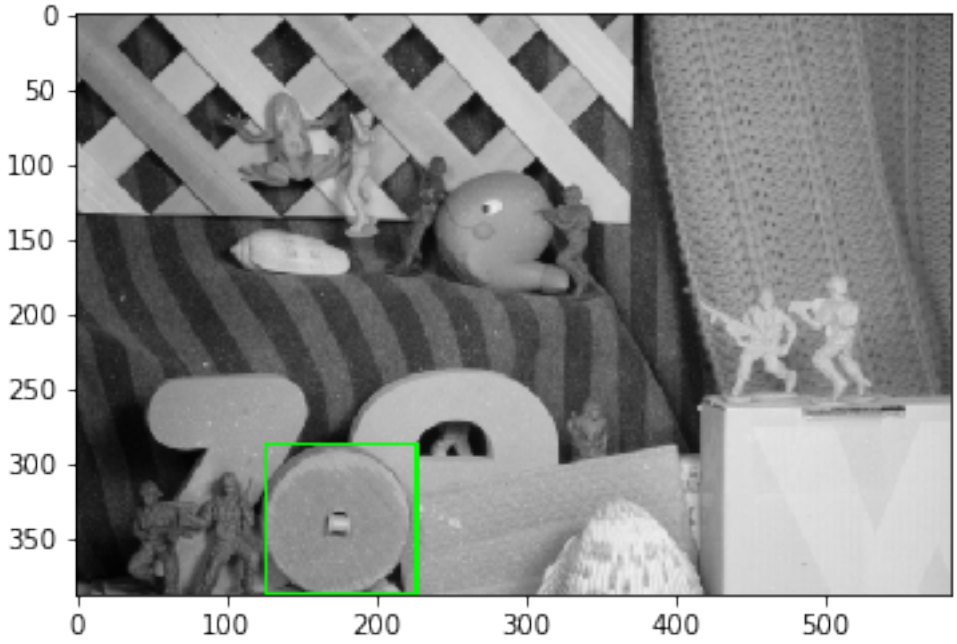
```
Optical flow computed
0.9922584465831683
[130, 287, 230, 387]
[129, 287, 229, 387]
```



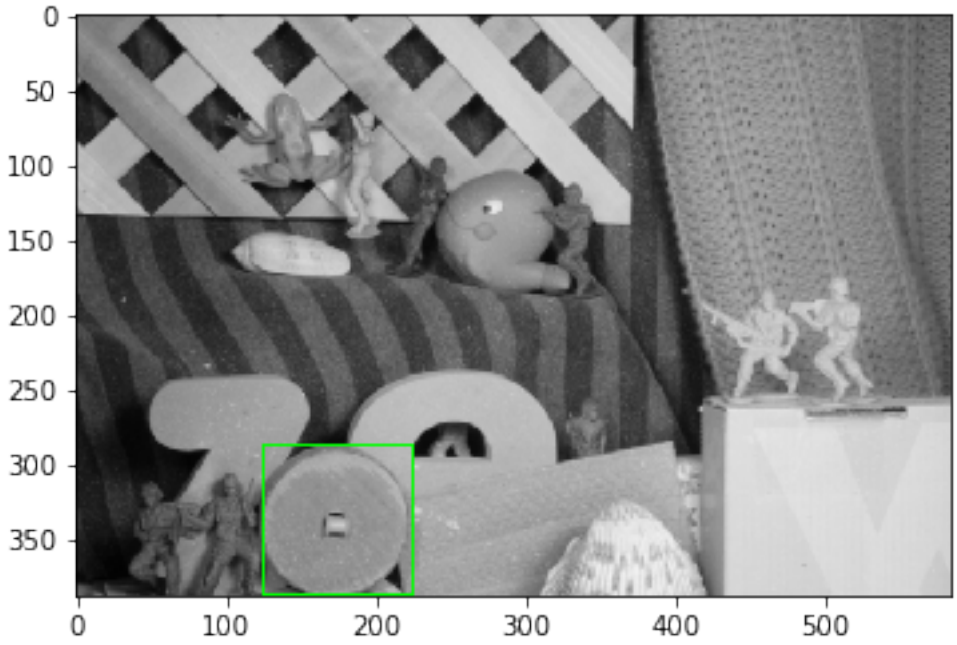

```
Optical flow computed
1.1979513086552462
[129, 287, 229, 387]
[128, 287, 228, 387]
```



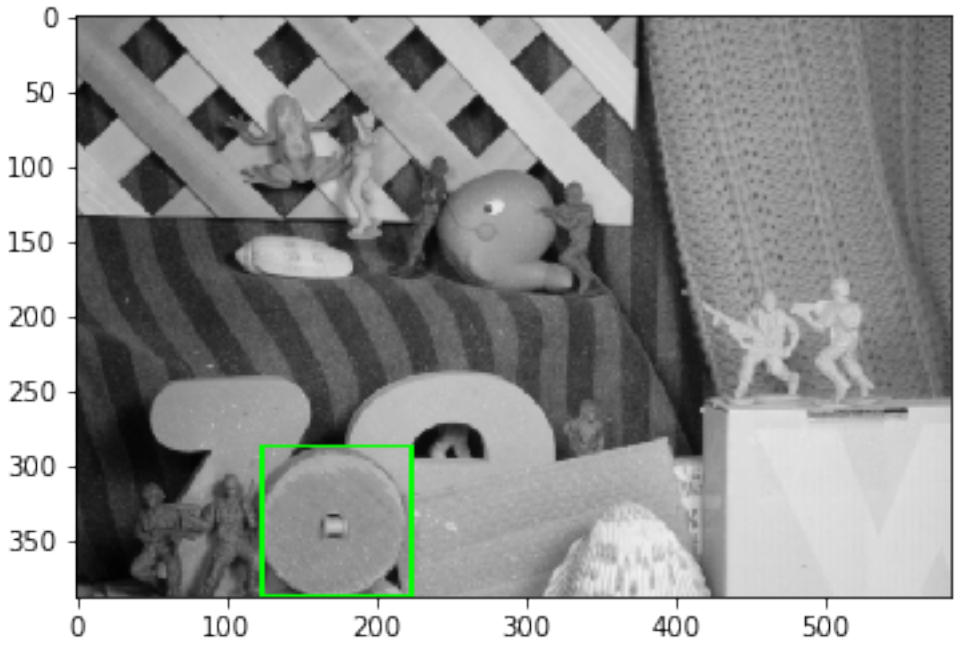

```
Optical flow computed
0.8840247808526494
[128, 287, 228, 387]
[127, 287, 227, 387]
```



```
Optical flow computed
0.8523037766728652
[127, 287, 227, 387]
[125, 287, 225, 387]
```



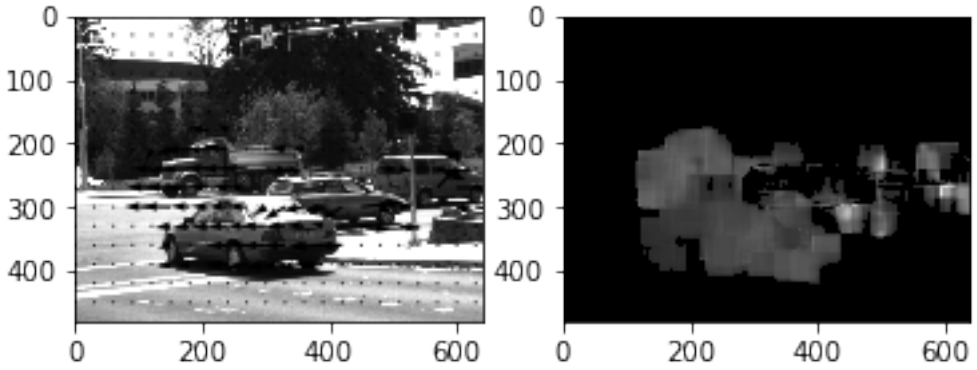

```
Optical flow computed
0.9090683717332151
[125, 287, 225, 387]
[124, 287, 224, 387]
```




```
saving images
Save complete. Output saved in ./outputs/Army
Video path ./outputs/Army/output/video.mp4
```

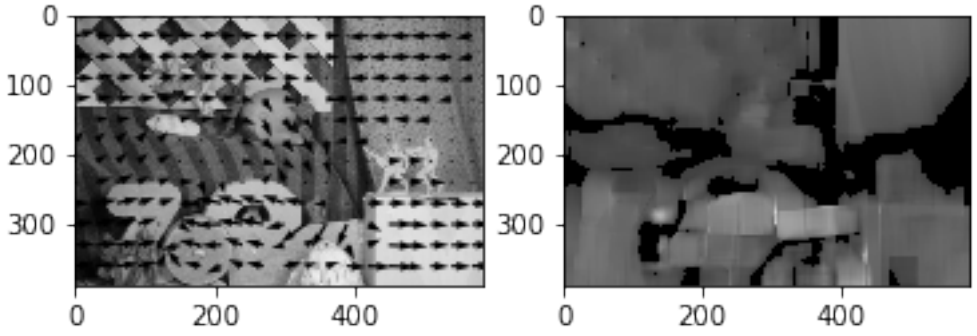
In [14]:
```
dataset = './eval-data-gray'

directory = '/Dumptruck'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
plt.subplot(121)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
plt.subplot(122)
segmentation(image_1, flow_matrix)
```

```
Optical flow computed
1.8176778334267094
```



In [15]:
```
directory = '/Army'
image_1_path = dataset + directory + '/frame10.png'
image_2_path = dataset + directory + '/frame11.png'

image_1 = cv2.imread(image_1_path)
image_2 = cv2.imread(image_2_path)
filter_size = ( 41, 41)
plt.subplot(121)
flow_matrix = compute_optical_flow(image_1 , image_2 , filter_size)
plot_flow_image(image_1, flow_matrix)
plt.subplot(122)
segmentation(image_1, flow_matrix)
```

```
Optical flow computed
0.8440589903756118
```



In [ ]: