CV2 Class02 of Unit01
Notebook Exercises #3

Assigned: 31/03/2023
Due: 17/04/2023

Objective:

- The purpose of the lab is to gain intuition with the trackers available in openCV
- The lab is limited in scope and does not require extensive testing
- This is a brief exercise; some (or most) of which could possibly be completed with the lab period. Your descriptions should be concise and not require a lengthy report. The exercise involves testing the code, making observations, and experimenting with minor changes to input parameters or optical flow algorithm choices.

Submission:

- The lab exercise consists of performing the following tasks The percentage of the points assigned to the lab exercise is given for each point.
- The submission should be in the form of a PDF file of your Jupyter Notebook output.
- The evaluations for this lab will be "qualitative," meaning they will be based on your visual inspection. At the end of this document, there are references to some of the commonly used performance metrics that you can keep in mind for your qualitative assessment. Additionally, there are a set of blog references for those who are interested, but implementing these is beyond the scope of the lab.

The Exercise

1. Basic Tracker Comparison
    1. In the provided Jupyter Notebook, compare **at least 2** trackers from (BOOSTING, MIL,KCF, CRST, TLD, MEDIANFLOW, MOSSE) and the GOTURN tracker.
    2. Use the provided video in the Jupyter Notebook and apply each tracker to track the race car throughout the video. Select a few moments in the video to visualize the results of each tracker side-by-side. You could qualitatively select what you think is the ground truth window and then get an approximate estimate of precision based upon the limited number of time points that you sample (recall that precision is the percentage of frames in which the predicted bounding box is within a certain distance

(e.g., 20 pixels) from the ground truth bounding box. A higher precision value indicates better tracking performance.)
3. Write a brief analysis of your qualitative observations and the tracking performance for each algorithm in terms of accuracy, speed, and robustness.

2. Tracker Performance with Lighting Variations and Occlusions
    1. Select at least two additional videos with varying lighting conditions and occlusions. A good source for such videos is the Visual Object Tracking (VOT) challenge dataset (https://www.votchallenge.net/challenges.html).
    2. Repeat the tracking process from Exercise 1 using the selected videos.
    3. Write a brief analysis of the performance of each tracker under the given conditions (lighting variations and occlusions). Discuss any improvements or degradation in tracking performance.

Quantitative Analysis.

To perform a quantitative analysis of trackers, you can evaluate their performance using various metrics. Some commonly used metrics are:

1. **Intersection over Union (IoU):** IoU measures the overlap between the predicted bounding box and the ground truth bounding box. It is calculated as the intersection area divided by the union area of both bounding boxes. A higher IoU value (close to 1) indicates better tracking performance.

2. **Center Location Error (CLE)**: CLE is the Euclidean distance between the center of the predicted bounding box and the center of the ground truth bounding box. A lower CLE value indicates better tracking performance.
3. **Precision:** Precision is the percentage of frames in which the predicted bounding box is within a certain distance (e.g., 20 pixels) from the ground truth bounding box. A higher precision value indicates better tracking performance.
4. **Success Rate**: Success rate is the percentage of frames in which the IoU between the predicted bounding box and the ground truth bounding box is above a certain threshold (e.g., 0.5). A higher success rate indicates better tracking performance.

To conduct a quantitative analysis, follow these steps:

1. Obtain ground truth annotations for the videos: You'll need annotated videos with ground truth bounding boxes for the objects being tracked. These annotations can be obtained from existing datasets (e.g., the Visual Object Tracking challenge) or manually created for your specific videos.
2. Apply the trackers: Apply the trackers to the videos and save the predicted bounding box coordinates for each frame.
3. Calculate performance metrics: For each tracker, compare the predicted bounding boxes with the ground truth bounding boxes and calculate the performance metrics (IoU, CLE, Precision, and Success Rate).
4. Visualize results: Plot the results in graphs, such as Precision-Recall curves, Success Rate plots, or bar graphs for comparison. This will help you to understand the performance of each tracker quantitatively and determine which tracker is best suited for your application.
5. Statistical analysis: Perform statistical tests (e.g., t-test or ANOVA) to determine if the differences in performance among trackers are statistically significant.

Here are some practical references that explain in detail how to perform a quantitative analysis:

[1] https://pub.towardsai.net/multi-object-tracking-metrics-1e602f364c0c
[2] https://pramod-atre.medium.com/understanding-object-tracking-a-hands-on-approach-part-1-3fb1afd0ae46
[3] https://github.com/cheind/py-motmetrics
[4] https://github.com/Videmo/pymot