Subject: Machine Vision Lab Project 02

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Abstract:

The rapid advancement of machine vision technology has opened up avenues for innovative solutions across various domains. This research specifically delves into the application of machine vision in road traffic analysis, aiming to create a robust system capable of extracting insights from video data pertaining to the dynamics of moving vehicles. Employing **MATLAB** for video processing, the system incorporates sophisticated techniques such as frame differencing, noise reduction, and region-based analysis. A crucial aspect involves the establishment of a reference frame, serving as a baseline for subsequent frame analysis that identifies regions of interest, predominantly focusing on vehicles.

The system dynamically tracks key metrics, including the number of regions, mean region size, and total region area, providing comprehensive statistics on traffic patterns over the course of the video. Bounding boxes strategically enhance the visual interpretation of the results. The project adopts a modularized approach in image processing and segmentation, contributing to improved code readability and maintainability. The outcomes are presented through a compelling video output and a detailed table summarizing region-based statistics, showcasing the practical application of machine vision in road traffic analysis. Beyond its immediate implications, this research holds the potential to influence fields such as traffic management, surveillance, and urban planning by providing a technological framework for informed decision-making.

Solving Strategy:

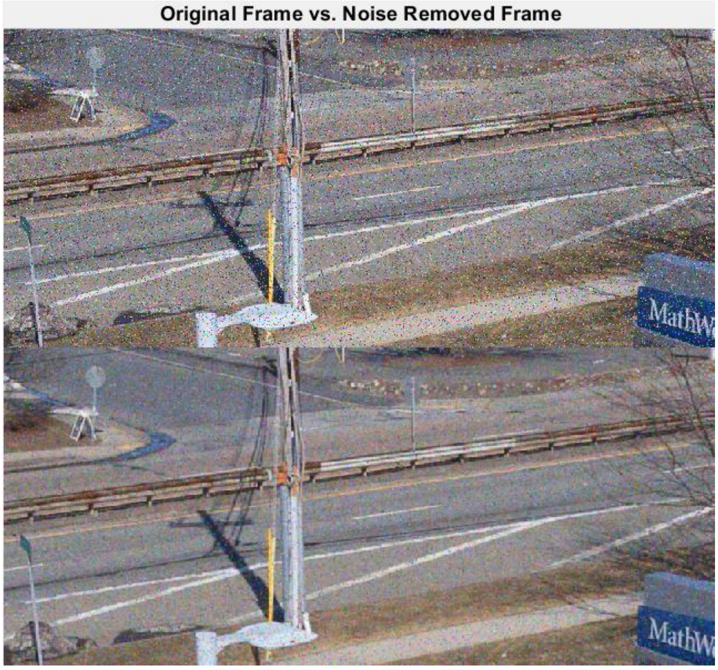
1. **Automatic Video Loading:**

The system uses automatic video loading to streamline the analysis process, eliminating manual intervention. This enhances efficiency and ensures consistent and accurate video processing tasks. The automation also enhances user-friendliness, aiming to create a seamless machine vision system for road traffic analysis.

2. **Noise removal from colored video**

The project was modified to handle colored video data, addressing multi-channel information intricacies. A Gaussian filtering approach was used for noise removal, smoothing variations in pixel values across all color channels. Each frame of the colored video underwent Gaussian filtering with an appropriate standard deviation to preserve essential visual information.

An example frame is shown below along with its processed version



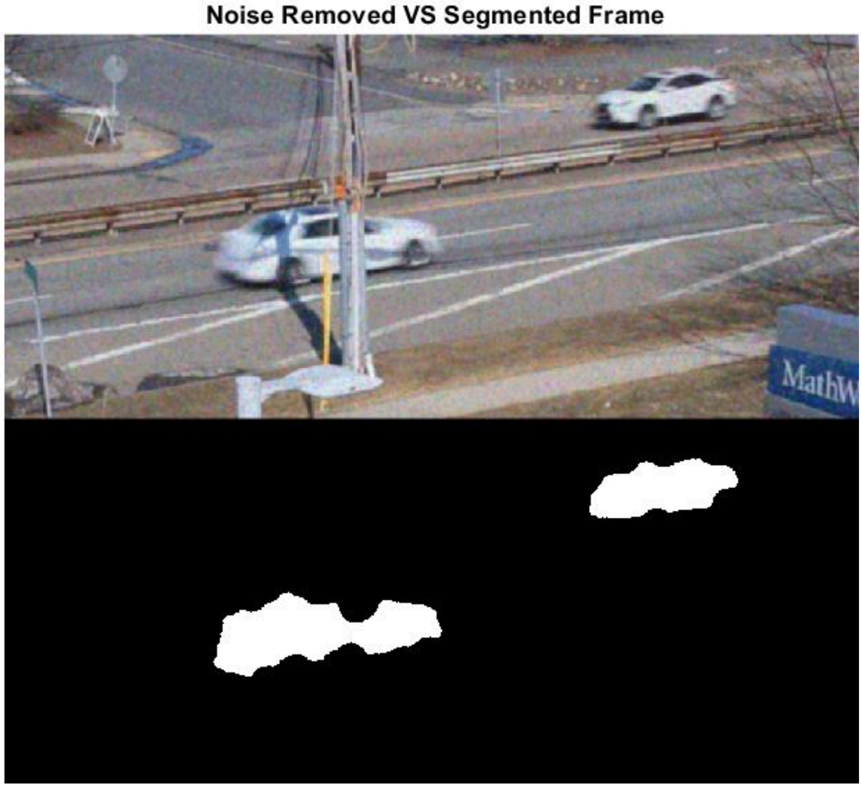
3. **Grayscale Conversion**

The project integrated colored video processing, leading to the use of a Grayscale Conversion step for uniform and efficient analysis. This pre-processing step converts each frame from RGB to a single-channel grayscale format, simplifying computations and enabling a standardized, channel-independent image analysis approach.

4. **Segmentation of Cars:**

The project involves segmenting vehicles within video frames to isolate and identify regions of interest for detailed analysis. This process distinguishes cars from the background, enabling precise tracking and characterization. The technique uses frame differencing and thresholding to extract salient features defining vehicle presence. Short summary is below

- Selecting a frame of reference (in our case, frame 1).
- Take the absolute difference between the reference frame from the rest of the frames, isolating only the moving car and eliminating all other obstacles, including the telephone pole.
- From the ImageSegmentor App, select **manual thresholding** and adjust the appropriate value, then apply morphological operations to refine the segmentation by eliminating undesired artifacts, ensuring the formation of a cohesive and singular region within the frame.



For dark and white cars collectively in single frame, the result is:

5. **Statistical Analyses:**

The project's analytical framework focuses on thorough statistical analyses of segmented regions within each video frame, extracting key metrics to gain detailed insights into vehicular dynamics as the processing progresses.

- **Number of Regions**: The count of distinct regions, representing individual vehicles within each frame, is a fundamental metric aiding in quantifying traffic density and vehicle distribution.

We utilize the **bwlabel** function to label the connected regions within the binary image obtained from the segmentation process. The count of the labeled regions is then extracted and stored for each frame in an empty array, providing the number of distinct regions (vehicles) identified in that specific frame

- **Mean Region Size**: This metric signifies the average spatial extent of segmented regions in a given frame, offering insights into the typical size of identified vehicles.

For this purpose, the **regionprops** function is employed to extract region properties, including the bounding box and area of each labeled region. The mean area of all segmented regions is then calculated using the "mean" function, providing a representative measure of the average size of identified vehicles.

- **Total Region Size**: The regionprops function is used to calculate the spatial coverage of vehicles in a frame by summarizing the areas of all segmented regions. This method provides a comprehensive understanding of the overall vehicular presence throughout the video, by computing region properties for each labeled region and aggregating individual region areas.

The final result in a tabular form:

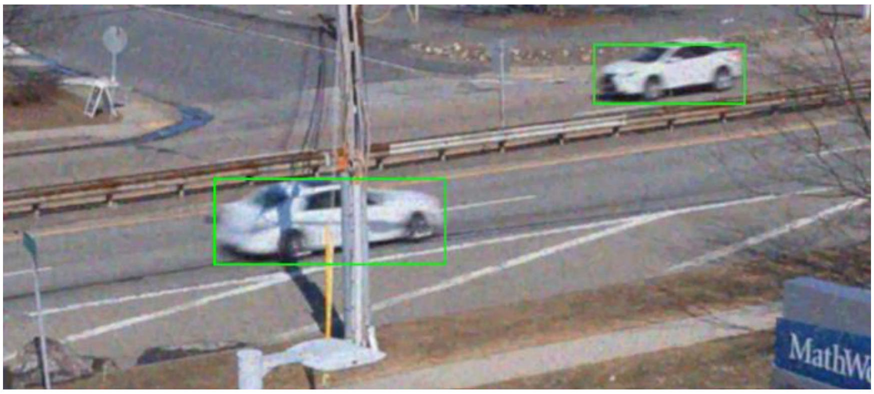
Frame-Number	Number of Regions	Mean Region Size	Total Region Size
67	1	10624	10624
68	1	10323	10323
69	1	10901	10901
70	1	11804	11804
71	1	12658	12658
72	1	8286	8286
73	2	803.5000	1607
74	1	12979	12979
75	1	25643	25643
76	1	21578	21578
77	1	18620	18620
78	1	20206	20206
79	1	19049	19049
80	1	18040	18040
81	1	17433	17433
82	1	15597	15597
83	1	15278	15278
84	1	12189	12189

✓ The data can be used to **distinguish between light and heavy vehicles**.

6. Tracking Box:

The video processing pipeline incorporates tracking boxes strategically drawn around identified regions, primarily representing vehicles, to enhance visual interpretability and contribute to a comprehensive analysis of vehicular dynamics. The **insertShape** function is used to meticulously draw bounding boxes on each frame after segmentation and statistical analysis, dynamically overlaying rectangular tracking boxes to encapsulate the spatial extent of the segmented regions.

The final response is:



Executive Summary:

- Read the video and store it in variable
- Initialize by selecting a reference frame (frame 1) and applying preprocessing (grayscale conversion, Gaussian filter).
- Implement a loop for each video frame, incorporating noise reduction, grayscale conversion
- The absolute difference between the current frame and the reference frame is calculated, revealing dynamic elements in the scene.
- From **ImageSegmentor** App, Segmentation techniques are applied to identify and isolate moving regions within each frame.
- Connected regions within the binary image obtained from segmentation are labeled using the **bwlabel** function.
- Region properties, including bounding boxes, mean region size, and total region size, are calculated using the **regionprops** function.
- Bounding boxes representing identified moving regions are superimposed on the original frames for visual representation.

Conclusion:

- The developed MATLAB script successfully addresses the task of video-based car detection and analysis in road traffic scenarios. The algorithm, characterized by a systematic approach, effectively identifies and analyses moving regions, particularly focusing on vehicles.
- The statistical analysis table provides a comprehensive overview of the detected regions throughout the video, offering valuable insights into the behavior and characteristics of vehicles
- The solution for the overlapping case remains unresolved; however, the implementation of machine algorithms (Like YOLOV5) holds the potential to address and resolve this issue
- The practical applications of this code extend beyond mere video analysis. Its contributions to traffic management, intelligent transportation systems, urban planning, security, and emergency response underscore its relevance in addressing real-world challenges and enhancing the efficiency and safety of transportation systems.