A Novel Image Processing Approach for Qualitative Road Traffic Data Analysis

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Abstract: Real-time qualitative road traffic data analysis is the cornerstone for any modern transport system. So far, most of the analysis is done manually and the use of image processing techniques for qualitative analysis is at its early stage. In this paper we concentrate on qualitative analysis of a traffic scene, which is describing the traffic scene similar to the description of a traffic expert when viewing the scene. The results demonstrate that the system can be used in real-world traffic situation and the results are reported on-line in a graphical form.

Keywords: Image Processing, Transportation, Pattern Recognition, and Segmentation.

1. Introduction
Effective traffic data collection is the cornerstone of the successful planning, maintenance and control of any modern transport system. The application of image processing techniques for automatic capture and analysis of road traffic scenes has been carried out by for several years [1-5]. Many researchers have proposed many algorithms and architectures over the past 10 years. However, most researchers working in this area have concentrated on quantitative analysis, such as counting number of vehicles, speed, type of vehicles etc.

The qualitative analysis, which is similar to a traffic expert describing a traffic situation, is at its early stage. The qualitative road traffic data analysis is major idea in this paper, which was initiated by some researchers [6,7], is to analyze a wider view of the path and evaluate a whole description of traffic status. In this paper we have concentrated on describing image-processing algorithms together with the results for qualitative road traffic analysis. The results obtained under various weather and traffic conditions clearly show that the proposed system can be used for real-world road traffic applications.

2. The Image Processing Algorithms
We use image-processing algorithms to analyze a wider view of the path and evaluate the whole description of traffic status. To approach this, we considered two major parameters of traffic status: the percentage of road occupied by vehicles and the very important for controlling, managing and monitoring any road traffic system. The qualitative description of a traffic scene can be used for controlling traffic lights and putting hazard signals on the road side, thereby warning drivers to slow down or direct them to alternative routes.

Traffic sensors are one of the most important fields of traffic control. These sensors usually include magnetic sensors or inductive loops, by which we can evaluate some parameters like number of passing vehicles, speed, length of vehicles, and some other quantitative parameters. The most significant disadvantage of these sensors lies in the fact that they can survey only a limited region of traffic path and cannot give an image of the whole path. A ma percentage of moving and stationary parts of this occupancy.

The algorithm developed for the data analysis automatically divides the scene into a number of blocks, based on camera parameters, number of lanes and the co-ordinates of the points required for analysis. In order to determine existence of vehicles in any region of a path, we detect the volume of edges, excluding the background part in that region. Detecting the vehicles based on edge detection insures the least dependency to variation of lighting condition, as the edges of a vehicle are less sensitive than its other features to lighting changes. This full frame image processing application requires a low-cost frame grabber and a Pentium-based microcomputer for on-line real-time operations.

3. The Processing Scheme
The edge detection operation used is based on morphological filters, which is less computational intensive and also is capable of extracting the edges independent of their direction. In addition to edges that are caused by vehicles, some of them may come from undesired factors like damaged road or white marks on the road surface and shadows of trees and buildings. To remove the effect of them, we differ the edges of background pictures from the edges of the current pictures. After detecting the existence of vehicles, we must determine the movement and status of the vehicles. To achieve this aim, we simply differ two successive pictures. If there is no movement, difference of the same grey level of pixels leads to a smooth dark context, while with moving vehicles, this difference leads to a higher grey levels and results in brighter pixels. After differencing, we apply an erode filter on the resultant image to remove any undesired impulses or thin lines which may be caused by minor vibration of camera.

In order to catch a whole description of the scene, we divide the traffic path into several parts; each of them is a rectangular box that includes between one to two vehicles on each lane. Then we determine the status of each box. This status could be one of the following cases:

- Stationary vehicle.
- Moving vehicle.
- No vehicles.

By assembling these boxes, the traffic status of a path or of a whole scene can be determined. A brief description of various conditions implemented on our system is described below:

- If there are more than half ‘vehicle’ blocks on a lane including stationary vehicles, then the traffic is heavy.
- If the number of ‘no Vehicle’ block is more than 50%, then light traffic is reported.
- If the number of moving vehicle block is more than 50%, or none of the two above conditions is true, then it is considered as a normal traffic flow.
- If a heavy traffic is reported for a specific period of time (for instance 5 minutes), very heavy traffic is reported.
- According to the place and the order of blocks, queue conditions are also detected.

Accident can be detected by knowing the place and status of blocks and its neighbors.

- When there are one or few neighboring ‘stationary vehicle’ blocks and one or few move or, stationary vehicle block is the rear block and none blocks are in the front, then the accident is detected.

4. Determining the Traffic Status

To determine status of each box, after applying necessary processes to extract edges and detect movement, we evaluate the two histograms of each box. Accumulating the contents of elements whose indices are above a certain grey level (for example 20), lead us to evaluate number of pixels that their brightness is significant enough. We call these numbers as edge-level and diff-level:

\[
\text{Edge-level} = \sum_{i=1}^{255} \text{edge-histogram}[I] \quad 1(a)
\]

\[
\text{diff-level} = \sum_{i=1}^{255} \text{diff-histogram}[I] \quad 1(b)
\]

Values of I1 and I2 can be selected arbitrary, but it must be selected in such a way that the values after counting will be significant enough. By comparing these parameters with threshold value we determine the existence and movement of vehicles in each box as shown in equations 2(a) and 2(b).

\[
\text{if edge-level > edge-threshold then}
\text{edge-parameter = 1} \quad 2(a)
\text{else}
\text{edge-parameter = 0}
\]

\[
\text{if diff-level > diff-threshold then}
\text{diff-parameter = 1} \quad 2(b)
\text{else}
\text{diff-parameter = 0}
\]

Once we have detected vehicle movement, the status of the traffic is determined as follow:

\[
\text{a) if edge-parameter =1 and diff-parameter = 1 then}
\text{status = Moving vehicles}
\]

\[
\text{b) If edge-parameter =1 and diff-parameter = 0 then}
\text{status = Stationary vehicles}
\]
5. Results and Discussion

We have conducted extensive experiments under various traffic and road conditions, for duration of 1 to 8 hours. The results of the algorithm were compared with the manual results in order to measure the effectiveness of the proposed algorithm. We get around 5% errors (figure 1). This is mainly due to vehicles not moving into their own lanes and frequently changes the direction. By placing extra boxes between the lanes, these errors can be significantly reduced. However, it will require more computing power. Since this error is within the acceptable range we decided not to use this technique in the final system. We use a DT287 frame grabber and a Pentium-based microcomputer system operating at a clock speed of 1.7 GHZ. We have achieved a frame rate of over 25 frames/second, which is adequate for qualitative analysis.

6. Conclusion

We have described a novel image processing based system for providing qualitative analysis of traffic conditions. This sort of analysis is usually done manually. In some cases, video footage is recorded and analyzed manually. We believe that with the use of image processing, these tedious tasks could be automatically achieved with an acceptable accuracy. The system is based on a low-cost Pentium-based PC, and thus the system does not require any special devices. Since the system runs on a standard PC, it can be easily interfaced to the network or to the central traffic control system. In this sort of situations, the traffic can be monitored at various places within the same city or around various cities within the same country. We believe that this system will be very useful for any country, particularly the big cities where traffic congestion is creating lots of problems.

References

Fig. 1 Traffic Status

Time