Real Time Vehicle Country of Origin Classification Based on Computer Vision

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• University of Zagreb, Croatia
  • Established in 1669.
  • 29 faculties and 3 academies
  • 4,850 research staff members and 50,000 students

• Faculty of Transport and Traffic Sciences
  • Established in 1984.
  • 15 departments
    • Cover all transport modes, logistics, ITS, aeronautics
  • 100 research staff members / 2,200 students
  • Publisher of the journal
  • PROMET – Traffic & Transportation
    • Cited in SCIE, TRIS, Geobase, FLUIDEX, and Scopus
Outline

• Introduction
• Problems and approaches
• Vehicle classification
• Vehicle detection and license plate recognition
• Vehicle detection speed up
• Experimental results
• Conclusion and future work
• Faculty of Transport and Traffic Sciences - Computer Vision Group
  • Developing algorithms for road traffic analysis based on computer vision

• Applications
  • Traffic management
    • Dynamic behaviour of a road traffic system derived from known parameters
      • Traffic flow between nodes in a traffic network
    • Driver information system
  • Origin-Destination analysis of traffic on highways
    • Computation of current and estimated OD matrices of a road traffic network
    • Possibility to estimate the route of a traced vehicle
• Problems of manual measurement of traffic parameters
  • Inaccurate data due to human error
  • Impracticable to measure data 24/7
  • Measuring number of passed vehicles on complex intersections requires a large number of people for counting
    • Increase need in human resources
  • Impracticable to measure complex traffic parameters (vehicles queue, vehicle velocity, distance between vehicles)

• Sensors for measuring traffic parameters
  • Pneumatic road tube sensors and piezoelectric sensors
  • Inductive loops and magnetic sensors
  • Radars, LIDARs
  • Video cameras (color, IR, multi-spectral)
Problems and approaches

Computer vision in traffic analysis

- Current commercial systems use one camera per lane
- Detection and tracking of vehicles
  - Based on performing segmentation between objects of interest and noninterest objects using various image processing methods (Fg/Bg image segmentation, optical flow, Haar method, Hough method)
- Estimation of vehicle trajectory
  - Based on knowing vehicle location at certain time
  - Describing vehicle movement by mathematical models which take into account vehicle dynamics
  - Estimating next possible location (trajectory) of the vehicle
Problems and approaches

• Trajectory of moving vehicle through road traffic network (from node A to node B)
  • Providing unique identification to each vehicle that is passing through road traffic network using automatic number (license) plate recognition
  • Reduction of false positive/negative vehicles using additional statistical information given from origin-destination (OD) matrix
• OpenCV framework for vehicle detection and localization
• CARMEN Freeflow SDK for license plate recognition (LPR)
• **Application objectives**
  • Detection of vehicles in video
  • Tracking static vehicles (if vehicle stops to move)
  • Vehicle license plate recognition for further traffic analysis

• **Vehicle detection**
  • Pre-processing image imported from video with Gaussian blur filter
  • Passing image through foreground / background image segmentation algorithm
  • Finding contours which localize regions of detected vehicles
• **Disadvantages of currently developed application**
  - Vehicle detection depends on license plate recognition
  - High requirements for system resources (slow execution of algorithm due to sub-optimal approach)

• **Optimization approach**
  - Executing algorithms on GPU as much as possible
  - Adding support for CPU SIMD instructions to algorithms which are incapable to run on GPU
  - Performing computations using multiple threads
    - Parallelization of image processing algorithms
### Experimental results

#### Accuracy and execution time

**• Accuracy**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Total evaluation time [min]</th>
<th>Real vehicle Count</th>
<th>Corrected Vehicles</th>
<th>Wrong Vehicles</th>
<th>Correct/Real [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis with sharpener filter</td>
<td>30</td>
<td>534</td>
<td>507</td>
<td>27</td>
<td>94%</td>
</tr>
<tr>
<td>Analysis without sharpener filter</td>
<td>30</td>
<td>532</td>
<td>515</td>
<td>17</td>
<td>96%</td>
</tr>
</tbody>
</table>

**• Execution time**

<table>
<thead>
<tr>
<th>Approach</th>
<th>Contours for loop</th>
<th>Processing time of an image with vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg time [ms]</td>
<td>Avg time [ms]</td>
</tr>
<tr>
<td>Single-thread</td>
<td>909</td>
<td>904</td>
</tr>
<tr>
<td>Multi-thread</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>
Experimental results

Vehicle classification

- Extracted classification of vehicles by its country of origin
  - Test video length - 30 [min]

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>NUMBER OF VEHICLE</th>
<th>RATIO [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>166</td>
<td>31.2</td>
</tr>
<tr>
<td>Poland</td>
<td>88</td>
<td>16.5</td>
</tr>
<tr>
<td>Austria</td>
<td>83</td>
<td>15.6</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>72</td>
<td>13.5</td>
</tr>
<tr>
<td>Croatia</td>
<td>47</td>
<td>8.8</td>
</tr>
<tr>
<td>Slovenia</td>
<td>17</td>
<td>3.2</td>
</tr>
<tr>
<td>Turkey</td>
<td>13</td>
<td>2.4</td>
</tr>
<tr>
<td>Slovakia</td>
<td>11</td>
<td>2.0</td>
</tr>
<tr>
<td>Others</td>
<td>35</td>
<td>6.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>532</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Experimental results

Arised problems

- Overlapping vehicles cause false positive and false negative detections
- Environment conditions (sun reflection, rapid lighting changes), camera vibrations caused by strong wind or passing of large vehicles
• Developed application has shown possibility of extracting a large number of information from video footage
  • License plate number – vehicle country of origin, vehicle trajectory, flow, number of vehicles, etc.
• One camera can be used for multiple lanes
• First results promising
• Further development of the application is currently in progress and it consists of following goals
  • Estimation of vehicle trajectory on a road traffic network
  • Detection and analysis of vehicle queue
  • Determination of vehicle velocity
  • Computation of origin-destination matrix of large road traffic network for purposes of traffic modelling
Acknowledgment

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  – Leading institution University of Zagreb, Faculty of electrical engineering and computing
• University of Zagreb, Faculty of Transport and Traffic Sciences
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