Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics

Presentation to Transportation Research Board Annual Meeting 2002
Paper No. TRB02-3920

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Video Detection of Vehicle Presence for Signal Actuation

Video cameras mounted on existing luminaires

Video processor in signal control cabinet

Typical stop line detection zones, one zone per lane
Typical Deployment

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Study Objectives

- Develop systematic objective evaluation methods and metrics for vehicle presence detection systems used for traffic signal actuation at intersections, with particular emphasis on video-based systems.
- Methods and metrics must address what really matters for intersection actuation.
- Three guiding principles for methods and metrics:
  - Metrics based upon absolute sensor accuracy
  - Results segregated by detection event class
  - Overall intersection performance may be inferred from test results
- Must be applicable to range of available systems and products.

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Advantages of Video-based Detection (compared with ground-based sensors)

- Rapid and possibly temporary deployment.
- Installation at intersections in which the pavement may not be suitable for fixed ground detectors (e.g., construction zones).
- Total cost may be attractive, in view of the expense and inconvenience required for the installation of in-ground detectors, especially for larger intersections with as many as five or six lanes per approach.
- Life cycles have the potential to be favorable in comparison, considering the excessive pavement wear in area of intersection approaches and stop lines.
- And systems of this type can easily measure and record additional traffic performance metrics, such as vehicle counts, queue length, vehicles speeds, or vehicle classifications.
- Possible improved detection accuracy, especially for unusual intersection configurations.

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Limitations of Video-based Detection

- Proper camera positioning and field of view is critical. But options are often very limited at intersections – must take what's available.

- Requires the prior existence or supplementary installation of support structures, typically for one camera per approach direction.

- Limited by ambient lighting conditions over 24 hour operation and non-advantageous camera field of view. Each deployment is different.
  - Some intersection orientations may require the placement of cameras with fields of view directly into the sun or pavement glare during some hours of operation, or with detection zones in areas of inadequate illumination at night.

- Fog or other atmospheric obscurants may limit resolution of detection zones.

- Dust or grime accumulation on optics requires frequent maintenance – not always an easy task.

- Power and signal routing between the cameras and the traffic control cabinet may be a challenge in some cases.

- Some systems operate as simple replacements for conventional sensors such as loops, while some incorporate knowledge of the current signal phase or time of day for optimization of the underlying image processing and...
Other Considerations and Characteristics

- Due to severe field of view and scene requirements, and sole dependence on ambient illumination, image processing requirements are extremely demanding; much greater than requirements for data collection systems.

- Yet operational requirements are more critical: drivers rely on proper signal actuation under all possible traffic conditions, at all times of the day, and all possible weather conditions.

- Some systems operate as simple replacements for conventional sensors such as loops, while some incorporate knowledge of the current signal phase or time of day for optimization of the underlying image processing and analysis algorithms.

- While ideal for some intersections, video detection may not be appropriate for all intersections in a large network. The cost of using different detectors at different intersections may defeat any economic advantages.
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Evaluation Criteria

- Information content of images
  - Vehicle or object detection
  - Vehicle or object identification
- Noise content of images
- Standard video performance metrics (resolution, dynamic range, image artifacts, geometric and intensity linearity, image time constant and effective frame rate)
- Technical advantages and limitations
- Human interface factors
- Reliability and robustness in traffic surveillance environment
- Potential for sensor fusion

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Normalized Overall Score

Weighted Average of All Test Conditions
Intended to Represent a Realistic Mix of Actual Operating Conditions

\[ \Sigma = \frac{1}{.638} \left( .097 \times C_1 + .146 \times C_2 + .049 \times C_4 \\
+ .049 \times C_5 + .049 \times C_6 + .194 \times C_7 \\
+ .016 \times C_8 + .022 \times C_9 + .016 \times C_{12} \right) \]

Notes: (1) \( C_i \) are % scores for each Test Condition.

(2) Conditions 14 (EMI), 19 (wires in view) and 20 (color camera) not included in score.
Normalized Overall Score
Vehicle Detection
9 Conditions Weighted, 135 Minutes, 1821 Actual Vehicles

Correct Detection: 68.8%
Detection w/Latch: 0.8%
Multiple Detections: 5.2%
Dropped After Detection: 2.0%
False Detection: 8.2%
False Detection w/Latch: 0.1%

Failure to Detect: 13.5%
Tailgate: 14.9%
Tailgate w/Latch: 0.1%
Normalized Overall Score
Phase Detection

9 Conditions Weighted, 135 Minutes, 1821 Actual Vehicles

All Phases

Correct R/G Actuation or Green Extension: 60.8%
Incorrect R/G Actuation or Green Extension: 39.2%
## Imaging Systems Tested

<table>
<thead>
<tr>
<th>Company and Product</th>
<th>Received Wavelength Band (μm)</th>
<th>Focal Plane Temperature and Cooler Type</th>
<th>Detector Type</th>
<th>Array Size (pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGEMA Thermovision</td>
<td>8 to 12</td>
<td>77 K Sterling</td>
<td>HgCdTe</td>
<td>5 elements, X-Y mechanical scan</td>
</tr>
<tr>
<td>Cincinnati Electronics IRRIS-256ST</td>
<td>3 to 5</td>
<td>77 K Sterling</td>
<td>InSb</td>
<td>256 x 256</td>
</tr>
<tr>
<td>FSI PRISM</td>
<td>3.6 to 5</td>
<td>77 K Sterling</td>
<td>PtSi</td>
<td>320 x 244</td>
</tr>
<tr>
<td>GEC/Marconi Sentry IR20</td>
<td>8 to 14</td>
<td>Ambient</td>
<td>Microbolometer</td>
<td>200 x 200</td>
</tr>
<tr>
<td>Inframetrics 600</td>
<td>3 to 5 and 8 to 12</td>
<td>77 K Cryogenic</td>
<td>PtSi and HgCdTe</td>
<td>1 element, X-Y mechanical scan</td>
</tr>
<tr>
<td>Inframetrics 760</td>
<td>8 to 12</td>
<td>77 K Sterling</td>
<td>HgCdTe</td>
<td>1 element, X-Y mechanical scan</td>
</tr>
<tr>
<td>Inframetrics InfraCam</td>
<td>3 to 5</td>
<td>75 K Sterling</td>
<td>PtSi</td>
<td>256 x 256</td>
</tr>
<tr>
<td>Insight/Starsight</td>
<td>8 to 14</td>
<td>Ambient</td>
<td>Pyroelectric BST</td>
<td>256 x 256</td>
</tr>
<tr>
<td>Mitsubishi IR-M300</td>
<td>3 to 5</td>
<td>77 K Sterling</td>
<td>PtSi</td>
<td>256 x 256</td>
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<tr>
<td>TI Nightsight</td>
<td>8 to 14</td>
<td>Ambient</td>
<td>Pyroelectric BST</td>
<td>256 x 256</td>
</tr>
<tr>
<td>TRW Multispectral Scanner</td>
<td>94 GHz</td>
<td>Ambient</td>
<td>HEMT*-heterodyne</td>
<td>1 element, X-Y mechanical scan</td>
</tr>
</tbody>
</table>

* HEMT = high electron mobility transistor

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Simulation: Good Visibility

Total Transmissivity in Radiation Fog

Path Length = 1.0 Km
Visibility = 5.0 Km
Simulation: Limited Visibility

Path Length = 1.0 Km
Visibility = 1.0 Km
Imaging Performance in Fog

Inframetrics 760 HgCdTe 8-12 um IR

Burle TC209 Color CCD Camera (Visible Reference)

Inframetrics Infracam FPA 3-5 um IR

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Conclusions and Observations Continued

- Except for a limited number of surveillance situations, infrared and millimeter-wave imaging technologies provide marginal or no net advantage compared with conventional color CCD video cameras.

- Special situations that may warrant the use of IR or millimeter-wave imaging:
  - Recurrent dense fog, smoke or dust, in combination with recurrent hazardous traffic patterns, where surveillance and intervention by TMC personnel could reduce traffic incidents or loss.
  - Situations in which temperature information in the scene is useful, for example, detection of overheated truck brakes for HOV inspection.
  - Machine vision applications in which consistent scene illumination is critical, or the rejection of shadows and/or glare is required for accurate detection or measurement.
  - Sensor fusion opportunities promising, due to fundamentally different information content and transmission characteristics of IR and mm-wave images.
"When evaluating the performance of these devices it is important to consider their intended applications. For example, if a device will be used to actuate a signal it is not necessary to obtain a highly accurate vehicle count. It is more important that the device detect the presence of every vehicle that approaches. In this case it may be acceptable for the device to double count some vehicles, or see multiple vehicles as one continuous vehicle, but it would not be acceptable to miss vehicles. Note that the focus of this project is to evaluate the ability of these devices to collect traffic data, not actuate signals or gather real-time traffic information."

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