Anomaly Detection using Microscopic Traffic Variables on Freeway Segments
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Introduction
This study proposes and assesses the effectiveness of monitoring vehicular traffic anomalies using microscopic traffic variables, namely relative speed and inter-vehicle spacing. In particular, we show that when applied to real-world scenarios, our algorithm can use the variance of statistics of relative speed to detect traffic anomalies and precursors to non-recurring traffic congestion [1]. The performance of the proposed algorithm is also assessed using a microscopic traffic simulation environment, where we show that with minimum prior knowledge, the proposed algorithm has comparable performance to an ideal placed loop detector monitoring the standard deviation of speed. The algorithm also performs very well even when the microscopic traffic variables are available only from a fraction of the complete population of vehicles.

Motivations & Aims
- The first step to proactively assess the occurrence of traffic incidents is to detect a deviation from normal traffic patterns, which we refer to as traffic anomaly.
- Most existing approaches are based on stationary detectors, e.g. loop detectors, where an anomaly can be missed if it takes place far away from the detectors’ locations, especially under low vehicle density.
- Emerging automotive navigation and roadside infrastructure technologies enable the measuring of microscopic traffic variables associated with individual vehicles, which are particularly useful for anomaly detection.
- Aim: develop a methodology that can utilize microscopic traffic variables for anomaly detection even when the information is available only from a fraction of the complete population of vehicles.

Analysis Framework
- The microscopic traffic information could be measured by vehicles sharing information through automotive navigation systems and wireless communications, or from roadside infrastructure.
- The statistics are calculated from Pol × L vehicles; Pol (Percentage of Availability) denotes the percentage of vehicles whose microscopic information can be measured, and L is the total number of vehicles on the segment.

Anomaly Detection Algorithm
- Anomaly detection is formulated as a variance change point detection by assessing the performance of microscopic traffic variables associated with individual vehicles, which are particularly useful for anomaly detection.
- Aim: develop a methodology that can utilize microscopic traffic variables for anomaly detection even when the information is available only from a fraction of the complete population of vehicles.

Performance Evaluations using Real-World Data
- In order to validate and assess the proposed algorithm, a freeway segment is analysed in which the microscopic traffic variables can also be obtained from a video surveillance camera [3].
- The freeway segment is part of the main route that links Bangkok to the Northern provinces of Thailand.
- The density of vehicles on the segment can vary with time and the vehicle density can be very low at certain periods. Pol = 100% is used to guarantee that there are always enough individual vehicle information for our analysis.
- The real-world cases are classified according to whether they lead to non-recurring congestion; anomaly cases that lead to non-recurring congestion are referred to as non-recurring congestion precursors, otherwise they are simply referred to as transient anomalies.

Preliminary Analysis using Simulation
- In Figure 1, anomalous condition is simulated from n₁ = 690 to n₂ = 750.
- Figure 1 shows that the proposed algorithm detects anomalies based on the fact that a short-time transient disturbance can cause a variation in the relative speeds.
- Table 1 also shows that for this experiment, inter-vehicle spacing is not a good anomalous indicator as the proposed algorithm has high false alarm rate.
- A reduction in false alarm rate is achieved by increasing Pol and/or sliding window size L, which enables the proposed algorithm to assess more relative speed samples [1].

REFERENCES

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FIGURE 1: Anomaly Detection on Single Simulated Realizations

FIGURE 3: Detection of Variance Change Point of Relative Speed and the Corresponding Video Snapshot

TABLE 1: Evaluations Results using Simulation: DR = Detection Rate, MTTD = Mean Time to Detection, FAR = False Alarm Rate.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>DRn1</th>
<th>DRn2</th>
<th>Pol (%)</th>
<th>Itotal</th>
<th>MTTD (s)</th>
<th>FAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>0.2</td>
<td>0.0</td>
<td>1.0</td>
<td>100</td>
<td>30.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Proposed</td>
<td>0.9</td>
<td>0.3</td>
<td>0.9</td>
<td>90</td>
<td>28.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 2 shows that the proposed algorithm can use the variance of statistics of relative speed to detect most traffic anomalies on the real-world data with MTTD less than seven minutes.
- One case that is falsely reported by standard deviation of relative speed alone occurred between two consecutive periods of non-recurring congestions.
- Three cases that are missed by average of relative speed alone occurred under high volume of vehicles (≥ 2000 vehicles/hour), which limit the change of variability of relative speed.
- We also note that there is preliminary evidence that detection times of transient anomalies could be used to estimate the times when the traffic flow and average speed evolve from free-flow to congestion [1].