AUTOMATIC INCIDENT DETECTION AND IMPROVED TRAFFIC CONTROL IN URBAN AREAS

Jeremy P Palmer, David J Bowers and Graham T Wall.

1. INTRODUCTION

Congestion is a problem in many urban areas. Vehicles are delayed, pollution increases and drivers become frustrated. As traffic levels gradually rise in the future congestion is going to become an ever increasing part of urban life.

Traffic incidents often cause or exacerbate congestion. A traffic incident could be an accident, a broken down vehicle or a slow moving lorry. If such incidents could be detected, action could be quickly taken to stop the congestion spreading around the network.

Automatic traffic signal control systems such as SCOOT try to optimise traffic signals to minimise delays to drivers. Although such systems work well in normal traffic flow, as a network becomes congested the ability to minimise delays is reduced. To improve this situation three systems have been developed: ASTRID, INGRID and MONACO. ASTRID is a database that monitors a traffic network and provides detailed information to a network operator about historic traffic conditions. INGRID is an online incident detection system that recognises unusual levels of congestion and MONACO is an online monitoring system that analyses recurrent congestion problems and suggests possible solutions. In the future it is hoped to develop these systems to take automatic remedial action to remove the congestion or prevent it spreading further.

2. THE ASTRID DATABASE

A traffic monitoring system called ASTRID - Automatic SCOOT Traffic Information Database, has been developed to store information from SCOOT in a form suitable for later retrieval and analysis. The ASTRID system gets information from SCOOT every minute. As well as the information direct from SCOOT, ASTRID also uses the data to derive further information types such as speed. ASTRID provides information on the expected state of the network at any given time using historical data. Information is available for a variety of data items eg. flow, delay, congestion and at several levels of detail eg. link, node, route. The ASTRID system enables traffic operators to manage a traffic network more effectively.

3. THE INGRID AUTOMATIC INCIDENT DETECTION SYSTEM

Congestion is often caused by traffic incidents. The INGRID system (integrated incident detection) has been developed to detect these incidents using information from adaptive urban traffic control systems such as SCOOT. Once an incident has been detected, information on the location and severity of the incident can be passed to the traffic operator. In the future, information on an incident could lead to automatic remedial action being carried out by the traffic control system.

3.1 Incident detection algorithms

INGRID uses two different algorithms to detect traffic incidents. One examines current traffic data for sudden changes in detector flow and detector occupancy. No reference data is required for this algorithm. To detect an incident, information from adjacent detectors must satisfy the following conditions:

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Detector upstream of incident, i.e. has a queue over it
  • occupancy greater than smoothed value calculated over recent minutes
  • flow less than smoothed value calculated over recent minutes
Detector downstream of incident, i.e. traffic flow less as cannot pass incident
  • occupancy less than smoothed value calculated over recent minutes
  • flow less than smoothed value calculated over recent minutes

The second algorithm uses the ASTRID database to provide historical reference data. This reference data is compared with current data obtained from SCOOT. This algorithm also requires data from adjacent detectors. For an incident to be detected the following conditions must be satisfied:
Detector upstream of incident, i.e. has a queue over it
  • occupancy greater than historical average
  • flow less than historical average
Detector downstream of incident, i.e. traffic flow less as cannot pass incident
  • occupancy less than historical average
  • flow less than historical average

Both algorithms minimise the possibility that normal fluctuations in traffic flow could cause the false detection of an incident by ensuring that each item, e.g. detector flow, is a considerable distance from the average before an incident is indicated. By varying this distance the sensitivity of each algorithm can be altered. The best results are obtained when traffic information is available for each traffic signal cycle.

3.2 Incident message output

The results from the two incident detection algorithms are used to calculate the severity and confidence associated with a detected incident. The severity is computed by measuring the number of detectors affected and the duration of the incident in minutes. The confidence that the incident actually exists is measured using the following information; the number of detectors affected by the incident; the duration of the incident and the number of algorithms indicating an incident.

This information is presented to the operator of the system as a message displayed on the INGRID computer screen. A typical message is given as an example below. The explanatory text in italics does not appear as part of a real message.

<table>
<thead>
<tr>
<th>Time</th>
<th>Date</th>
<th>Detector</th>
<th>Region</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:18:23</td>
<td>20051995</td>
<td>N07111A1</td>
<td>REG SW</td>
<td>08 Minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Confident of a moderate incident</td>
</tr>
</tbody>
</table>

List of affected detectors
  Affected up: N07121J1
  Affected down: N07123B1

3.3 Results of INGRID evaluation

Following the trials of INGRID with different threshold levels, optimum values were chosen. Results from each algorithm were then combined to give values for severity and confidence associated with each incident. The INGRID incident detection system has been found to operate most successfully when there is a short distance (less than 100m) between detectors. Final results are given in table 1 at the end of this paper.

4. THE MONACO TRAFFIC MONITORING SYSTEM

4.1 Introduction

MONACO (monitoring and analysis of congestion) is an on-line system that monitors an urban area under SCOOT control. Levels of Wasted Capacity are measured along routes in the network and excessive amounts are reported to the operator via a graphical display. MONACO is particularly useful for recognising regular
congestion. Having detected a congestion problem, MONACO analyses it to look for the most likely cause and attempts to offer a possible solution.

4.2 Wasted Capacity, routes and critical links

MONACO uses Wasted Capacity, measured in SCOOT's Link Profile Units (approximately 17 LPUs equate to one vehicle), as a measure of the problems caused by congestion. The Lost Capacity, defined as the total time in seconds that a link is blocked during its green stage multiplied by the link's saturation occupancy (the maximum flow of traffic possible per second), is calculated first. The Lost Capacity measures the total flow potentially lost on a link. Secondly, the Queue at end of Green is measured. This is the amount of queue remaining on a link when the traffic lights go red, reflecting the amount of flow that was unable to pass the stop line. Wasted Capacity is then the lesser of these two values. This definition reflects the fact that there may be no more queue to disperse from the link and so no vehicles were prevented from moving by the blocked junction exit. So, Wasted Capacity for a SCOOT link is defined as:

\[
\text{Wasted Capacity} = \min \{ \text{Lost Capacity}, \text{Queue at end of green} \}
\]

Wasted Capacity is measured along routes that traverse a SCOOT network. A route is a series of SCOOT links that form a path through the area under SCOOT control, such as the example shown below:

\[
\text{Link A} \rightarrow \text{Link B} \rightarrow \text{Link C} \rightarrow \text{Link D}
\]

The interpretation of the levels of Wasted Capacity on different links in a route enables discovery of the critical link. The critical link is the link suspected of causing Wasted Capacity upstream on a route. Should several links have high levels of Wasted Capacity and then the next link downstream have little or none it is probable that this link has some form of obstruction on it. The critical link is defined as the first link in a route after severe Wasted Capacity with little or no Wasted Capacity. For example, in the above route, if the levels of Wasted Capacity were 550, 650, 0 and 0 LPUs respectively, then Link C would be the critical link and the node (or junction) that Link C approaches would be the critical node.

4.3 The MONACO system

MONACO studies all the routes through the area under observation looking for build ups of Wasted Capacity. Having detected serious levels of Wasted Capacity, MONACO studies the congested route and determines the likely location and cause of the problem. The diagnosis is governed by the 'decision tree' shown in figure 1.

MONACO uses the decision tree to determine the probable cause of Wasted Capacity along the route in the monitored area. An example of how MONACO does this is given below, using the route mentioned above:

1. Wasted Capacity is measured along the above route. At the end of the five minute interval the levels of Wasted Capacity on this route are considered to be excessive.
2. Each link in the route is examined. Wasted Capacity is found on Link A and Link B, none is found on links Link C or Link D. This identifies Link C as the critical link.
3. MONACO starts at the root of the decision tree (the top in figure 1). The question here asks 'is the critical link heavily over saturated?'. This is the case, so MONACO follows the 'yes' path from its current position on the decision tree.
4. MONACO arrives at another question in the decision tree. The question here asks if there is a faulty detector at the critical node. This is also true, Link \( C_1 \) that approaches node C has a faulty detector. Again, MONACO follows the 'yes' path from its current position on the decision tree.
5. MONACO arrives at a position in the decision tree with no questions. The position explains the probable cause on the Wasted Capacity as Default split wrong. So, for this example, MONACO would output a message stating the problem is likely to be associated with the default split for Link \( C_2 \) (the faulty link).
4.4 Application of MONACO

MONACO was installed in London in July 1994 and has been monitoring 120 links in the Oxford Street / Regent Street area. The system is situated in London's central traffic control centre and aims to provide information to traffic engineers controlling the network.

The function of MONACO is to record regular occurrences of congestion, as opposed to irregular incidents, and to analyse the problem and report possible explanations. The possible causes of the congestion can then be considered by an operator who can then take the appropriate action.

4.5 Evaluation of MONACO

The MONACO system has been monitoring part of the London SCOOT network since July 1994. Congestion caused by problems with the network have been observed and remedial action has been suggested to the operators of SCOOT in London. These problems have included unvalidated links, over saturation of junctions (possible locations for gating strategies) and congestion problems directly caused by faulty detectors.

5. CONCLUSION

The ASTRID and INGRID traffic monitoring systems have been successfully installed in Southampton. ASTRID and MONACO has been successfully installed in London. All systems provide useful information to traffic operators who are then able to manage the traffic network more efficiently. Connections have been made in Southampton to supply automatically a central information system with details of incidents and current flow levels.

The detailed evaluation of INGRID shows that both incident detection algorithms can successfully detect severe traffic incidents. When the algorithms are combined to give information on an incident's severity and confidence level it is recommended that a message is produced only once the 'mildly confident' level is reached. This stops the frequent incident messages at the 'not confident' level reducing the effectiveness of the incident detection system. With this specification, INGRID detected all six severe incidents during an evaluation period of 540 hours with a median detection time of 4 minutes and 0.006 unconfirmed incident messages per junction per hour.

MONACO is providing useful information on the long term operation of a network, highlighting inaccuracies with the SCOOT database, over saturation of certain junctions, and problems caused by faults.

6. FURTHER WORK

To include ASTRID and INGRID with a SCOOT system currently requires modification by the signal company supplying SCOOT. The new version of SCOOT to be issued later this year will contain the required interface as standard. MONACO could be added as part of the standard SCOOT system in the future.

INGRID has been developed to detect incidents and pass information to the controlling traffic engineer. The engineer could then alter the traffic signals around the incident to reduce congestion. By directly linking INGRID output with SCOOT it may be possible to automatically alter the signal timings in the region of an incident. To carry out UTC changes successfully, INGRID will need accurate information on the effect of the incident on the capacity of surrounding links. With this information, INGRID could then allow larger alterations in signal timings than under normal SCOOT control. Alternatively the saturation occupancy of surrounding junctions could be changed.

To assess the effectiveness of INGRID in detecting moderate incidents requires more on street information to provide a detailed description of individual incidents. Such an evaluation would involve the presence of on street observers so that detailed descriptions of incidents could be recorded. This is difficult because incidents do not occur at well defined locations and times.
Further work is planned to expand the current coverage of MONACO to other areas of the London SCOOT network. MONACO may also be installed as part of other SCOOT systems. This would enable further testing and a possible expansion in the number of problems MONACO currently recognises.

7. BIBLIOGRAPHY


Table 1: Results of INGRID evaluation

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Unconfirmed incident messages per junction per hour</th>
<th>Median time to detect incident / minutes</th>
<th>Detection rate of severe incidents / %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Confident</td>
<td>0.093</td>
<td>0.5</td>
<td>100</td>
</tr>
<tr>
<td>Mildly Confident</td>
<td>0.006</td>
<td>4.0</td>
<td>100</td>
</tr>
<tr>
<td>Confident</td>
<td>0.004</td>
<td>5.5</td>
<td>100</td>
</tr>
<tr>
<td>Very Confident</td>
<td>0.003</td>
<td>6.5</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 1: Decision tree used by MONACO

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