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Decision Support for Intelligent Traffic and Environment Management

V. Suresh, P. Watson, M. C. Bell, J. Neasham.

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About the author

Lakshmi joined the computing science department as Research Associate in the MESSAGE project in November 2006. She received her Bachelor of Engineering degree in 1996 from the Bharatidasan University, India and the Master of Science(SDIA) with distinction in 2006 from the Newcastle University, United Kingdom. After completing her bachelor's degree she worked for LogicaCMG and Indigo4 Systems United Kingdom in client server technologies. During her post graduation studies, Lakshmi worked for PrismTech in the Open Splice DDS, a middleware addressing publish-subscribe communications for real-time and embedded systems.

Paul Watson is Professor of Computer Science and Director of the North East Regional e-Science Centre. He graduated in 1983 with a BSc (I) in Computer Engineering from Manchester University, followed by a PhD in 1986. In the 80s, as a Lecturer at Manchester University, he was a designer of the Alvey Flagship and Esprit EDS systems. From 1990-5 he worked for ICL as a system designer of the Goldrush MegaServer parallel database server, which was released as a product in 1994. In August 1995 he moved to Newcastle University, where he has been an investigator on research projects worth over £13M. His research interests are in scalable information management. This includes parallel database servers, data-intensive e-science and grid computing. In total, he has over thirty refereed publications, and three patents. Professor Watson is a Chartered Engineer, a Fellow of the British Computer Society, and a member of the UK Computing Research Committee.

Suggested keywords

INTELLIGENT TRANSPORT SYSTEM,
INFORMATION MANAGEMENT,
UTMC,
DECISION SUPPORT SYSTEM AND CONGESTION

Decision Support for Intelligent Traffic and Environment Management

V. Suresh[†], P. Watson[†]

M.C. Bell* J Neasham**

[†]School of Computing Science, *School of Civil of Engineering and geosciences
**school of Electrical, Electronic & Computer Engineering

Newcastle University

ABSTRACT
In this demonstration proposal, we will deliver the design and implementation of a static and mobile detector system for monitoring traffic and pollution in existing road networks. The measured data comes from networks of low cost, pervasive sensors referred to as "smart motes" as well as legacy monitoring stations. These provide real-time information on traffic, pollution and meteorological conditions. The data collected is processed and analyzed so that it can be used to drive applications in real-time to monitor network status and manage traffic to reduce congestion, improve air quality and manage noise impacts.

Keywords
Intelligent Transportation Systems, Information Management, UTMC, Congestion and Decision Support System.

1. INTRODUCTION
Mobile Environmental Sensing Across Grid (MESSAGE) [2] is a project jointly funded by the EPSRC and Department for transport, UK , aims to develop an environmental pervasive sensor system for urban road networks. Newcastle University has developed wireless sensors which are fixed in the street infrastructure, carried by vehicles and pedestrians thereby collecting data relating to the pollution and traffic at a very high spatial resolution. The collected data is sent, using wireless GPRS links in real-time, to the central server where more detailed analysis, processing and dissemination of information takes place. This forms the basis of the decision support system which provides information to monitor the status of the network in the short term as well as daily, weekly, monthly and annual average concentrations for longer term environmental assessments using a user friendly interface for decision makers.

2. MOTIVATION:
Current UK government policy has two key objectives, the first to tackle congestion (Eddington Report, 2006) and secondly to reduce carbon emissions by 60% by 2050 (Stern report, 2006). The responsibility for delivery of these goals rests with local authorities who will need to make tough decisions. The effectiveness of technical and policy decisions depend on the accuracy, timeliness and appropriate information available. Data is needed from static (attached to street furniture), mobile (located on vehicles, cyclists and pedestrians) and diverse data sources, at different sampling rates and spatial diversities. Capturing, synchronizing, cleaning, manipulating and processing present huge challenges especially when information is needed quickly across large spatial networks. For example optimizing traffic flow, delay and stops to identify traffic signal plans to improve the traffic performance of a network. Alternatively, traffic queues can be, relocated from a closed to open space to enable the natural ventilation of the built environment to disperse pollution and thus prevent build up of pollution hotspots. The capture of the data has to be supported by statistically sound data analysis often associated with modeling to derive effective solutions to network problems.

To date, many research activities have been undertaken to build transport warehouse for the collection of traffic data. However, substantial analysis of this data has to be achieved offline and it is rare for historic and real time data to be integrated with models to create an intelligent decision support system. This work seeks to develop an online information management system for measuring, managing and mapping traffic and pollution.

3. FRAMEWORK:
The overall aim is to provide a general framework for supporting the real-time and historic analysis of transport data, moving away from current ad-hoc approaches. This novel prototype system is currently deployed in Gateshead in the United Kingdom and later in the year its transferability will be demonstrated in Leicester and next year in London. Consequently, it has been designed to handle very high data input rates from hundreds of sensors, along with the analysis of very large amounts of historic data (collected over 20 years) in the warehouse.

Data from the UTMC [1] compliant database is cleaned, filtered and transformed into a Data Warehouse. The data is used by applications and users to explore historic trends and derive predictive mathematical and micro simulation models. These models can then be used by the real time applications to inform decisions taken to reduce congestion and pollution.

The framework uses the Oracle database 11g [8], Oracle sensor edge server and Oracle Business Intelligence tools are being customized for the data mining. The architecture for the data capture and processing is shown in figure 1.

Along with the sensor network, other streaming events are collected from data sources such as inductive loop traffic detectors. Data management is categorized in three different aspects namely real-time monitoring, historic data analysis and integration of real-time events with historic analysis for decision making. To handle the linearly increasing data volume, data warehouse with dimensional design is implemented. The concepts of star transformations, various techniques of partitioning, indexing and materialized views are being used to achieve the desirable query performance. With reference to Intelligent Transport Systems, various levels of aggregations are carried out to slice and dice the data for knowledge discovery and to meet the needs of different application domains for example transportation, traffic micro simulation, air quality , noise models evaluation, impact assessment and so on.

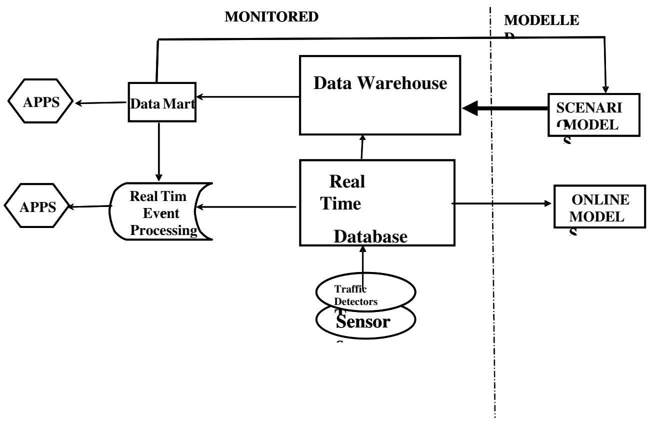

Figure 1: Information Management Framework

4. Data Analysis:

The data analysis is classified in to two different categories namely real time processing of the streaming events and the historic analysis using relational and dimensional modelling respectively. Relational schemas are created using the normalized modelling techniques and adopting UTMC standards as specified by the Department for transport. The dimensional schema is carried out in accordance with the work of Ralph Kimball [3].

The real-time streaming data undergoes quality assurance. In addition as appropriate calibration of sensors based on the temperature and humidity measured simultaneously at each location is achieved by applying business rules to classify the data based on their origin. In addition to the temperature and humidity correction, calibration [12] process corrects the data collected by the sensors in terms of the drift and manufacturers offset specified in the electrochemical hardware components.

Historic data marts are being created for calculating the daily pollution and traffic flow profiles. The data marts are referred with different dimensions based on the time, location of measurement, type of the device and meteorological conditions. In a typical road network, the intersection of two roads is referred to as nodes and the road segments between these intersections, the nodes are links. Historical analysis is started at the link level for mining patterns of traffic flow. For each link, the traffic flow pattern is analyzed and relationships are derived for congested, busy and free flow of traffic [4] for example as shown in the figure 2. These relationships are used to create algorithms to support the decision making queries to be programmed for applications.

The congestion parameter may vary for each and every link and node in the real-world scenario and the challenge here is to develop generic statistical methods to automatically create the intelligence needed to deliver the decision support. In order to monitor the regional pollution and traffic, data from thousands of links and nodes should be processed. The pattern of pollution and traffic varies according to external influences such as accidents, events including football match, road works etc. which occur at random or preplanned. To develop strategies for the traffic control and management systems, the data is fed into simulation models such as AIMSUN [7] to develop scenarios, explore potential solutions and present the visual real time display of the road condition. The pollution emission and dispersion is calculated by feeding the data to air quality models such as Airviro[6] to estimate the pollution in a particular location. The monitored pollutants, CO and NO2 are data mined for different locations and patterns are investigated to allow forecasting of future events or trends to provide timely and more effective decision support

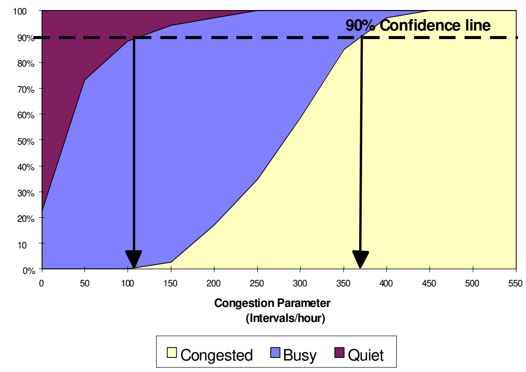

Figure 2: Flow Profile

5. Demonstration Features:

Four features will be demonstrated as examples of use cases currently being developed in the MESSAGE system.

5.1 Real Time Streaming Data:

1. Live display of pollution levels in a city using data directly from static sensors on Google maps as shown in Figure 3.
2. Minute by minute updated values of the pollutants measured like CO, NO_2 and noise along with meteorological conditions such as temperature and humidity.
3. Most recent 3 hours pollution profile as graphs.

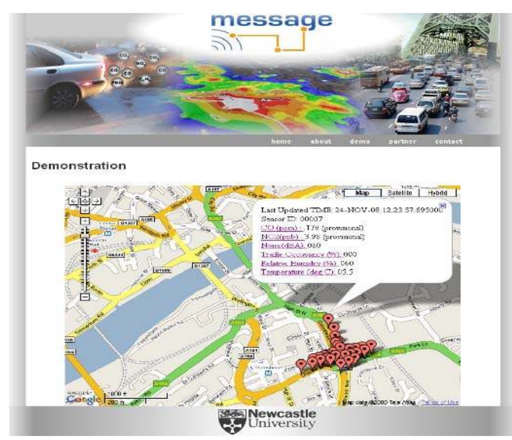

Figure 3: Real time pollution monitoring

5.2 Historic Data (Graphs):

- Derived historic patterns in data in terms of pollutants e.g. CO, NO_2 and traffic flow.
- Graphs to show how pollution builds up on a particular road network node on a Monday morning between 8:00 and 9:00 excluding Bank holidays.
- Changes in pollution levels in a day at a particular location.
- Changes in pollution levels along a particular route

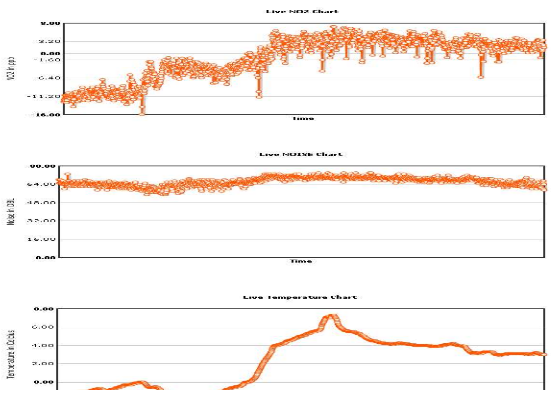

Figure 4: Historic daily patterns of measurements

5.3 Decision Support System

The decision support system is created by the integration of the historic and real time data sets. The historic patterns that are obtained by mining the data and subsequent statistical analysis 'history' of the analysis are compared with real-time data sets.

- Analyze historic data for each link in a network in order to enable free flow, busy and congested status of the road subsequently to be established and displayed in Google maps. In real-time the traffic occupancy and queuing is compared with the historic status and displayed in the map in terms of color coded lines indicating different traffic situations is shown on a map, see figure 5.

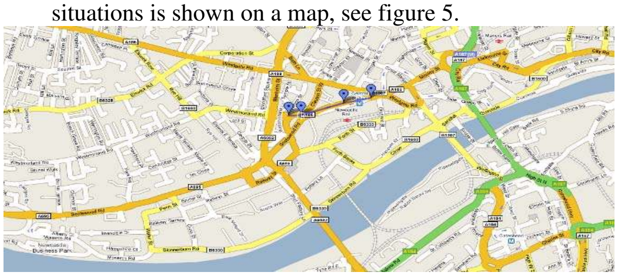

Figure 5: Real-time congestion status

5.4 Backup Scenario

The demonstration from various locations like Gateshead and Leicester from United Kingdom will be shown live using internet. In case of the network failure or slow links, a demo data set which simulates the real time system will be prepared and run using a laptop.

6. CONCLUSION

This demonstration will show integration and management of data from disparate data sources in the context of both real-time and historic analysis. As a basis for deriving meaningful information from the data sets for Intelligent Transport Systems which is subsequently to define and implement appropriate control and management actions. Various standards and business policies have to be applied to ensure stakeholder operating requirements are met. The life cycle of the data from various data sources involves real time data capture, processing, storage, analysis and dissemination. Combining real-time data from data sources such as pervasive sensors with existing legacy traffic systems will not only improve knowledge in traffic flow, congestion and pollution but should also reveal new information for more effective control and to achieve added value from Intelligent Transportation Systems implementation.

7. ACKNOWLEDGMENTS

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