Computational intelligence, and its role in enhancing sustainable transport systems

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Abstract

DeMontfort University's (DMU) Centre for Computational Intelligence (CCI), is engaged in a range of programmes applying modern Computational Intelligence (CI) techniques to provide superior analysis of complex real-time data sets that arise within transport systems. Better use existing transport infrastructures can achieve positive sustainable outcomes, reducing congestion, improving air quality, providing real-time travel information and supporting low carbon vehicles. This is exemplified by the following examples.

- ITRAQ, an integrated CI system that uses live feeds to determine the optimum use of the road system to reduce congestion and to improve air quality.
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- Sustainable Airport development Decision Support Systems. A CI based model that interfaces with a GIS system to model the environmental impact of flight paths.
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- The application of CI to solve multi-variable systems, logistics and passenger information
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- VenusSim. The use of CI to model the dynamics of customer flows in transport terminals.

Keywords: Computational Intellignce, Artifical Intelligence, Intelligent Transprt Systems

1. Introduction

Europe's transport infrastructure is reaching capacity, requiring new and innovative techniques to maximise the usage of the existing network. Positive economic and environmental impacts can be achieved without the need to invest in new systems, and capital intensive development. Intelligent Transport Systems (ITS) are playing a growing role in supporting the transport infrastructure; including delivery of logistics solutions, active traffic management and passenger information services. These systems however tend to be based on classical algorithmic solutions. De Montfort's Centre for Computational Intelligence (CCI) specialises in the application of CI techniques to provide alternative solutions that are better able to handle the varied multi-dimensional nature of transport related data.

This presentation presents a range ITS systems that have been developed and deployed by the CCI, covering air quality improvements, congestion management and crowd control.

2. iTRAQ - Integrated Traffic Management and Air Quality Control Using Space Services

iTRAQ will deliver a dynamic traffic management system for optimising use of the road network balanced with the need to sustain high standards of air quality. Financed by the European Space Agency's Integrated Applications Programme, the consortium of industry, academic and local authority partners combines expertise in intelligent traffic management, applying GNSS, developing air quality applications using Earth Observation and other GMES technologies.

Consortium partners are Infoterra , Leicester City Council, DMU and Leicester University. Operational priorities for iTRAQ are to mitigate traffic congestion, improve public transportation network delivery and improve air quality. The system will use downstream space services from GNSS and GMES, integrated with intelligent traffic management technology, to deliver real-time optimisation strategies for urban traffic flow and air quality management.

iTRAQ is a project to develop a dynamic traffic management system for optimising use of the road network whilst meeting growing demands to sustain high standards of air quality in urban environments. This part of the project is a one year feasibility study to develop a system concept around an existing operational traffic control system in use in the City of Leicester, augmented with traffic flow and air quality information and near real-time data from space and in situ measurements.

Congestion within urban environments is a significant factor in journey time, fuel efficiency, driver frustration, total carbon emissions, and local air quality. Traffic densities are increasing, with improvements in emission rates failing to provide the necessary compensating impact on air quality. Therefore, systems are required to jointly manage traffic flows and air quality in urban environments, to optimise the efficient movement of people and goods, while protecting the health of residents and visitors to major cities. Local air quality can be significantly impacted by the spatial distribution of congestion-related emissions, with this scheme offering unprecedented capabilities in assessing and managing the impact of the position of congested traffic. Operational priorities for iTRAQ are to mitigate traffic congestion, improve delivery from public transportation networks, and improve air quality. These priorities are driven by local, national and European level policy in the areas of air quality, local transport and climate.

The iTRAQ system provides advice in near-real-time to local authorities on an integrated strategy for both traffic management and air quality. In particular, near real time guidance on desirable traffic flows is produced which, in a fully-implemented system, can be routed to either traffic light control systems or automated signage to influence and optimise traffic density. The core of the system is a computational intelligence module that estimates the optimal solution which weighs up factors of user priorities, current and forecast traffic flows, and current and forecast air quality. Air quality information is supplemented by both ground-based remote sensing data, background field data from the Ozone Monitoring Instrument (OMI) on the AURA satellite, and space-borne meteorology data. These data streams are integrated with traditional ground-based sensor networks for both traffic and air quality.

The overall objective of this study is to establish whether an integrated system of traffic and air quality management, strengthened through the use of GNSS, air quality and meteorology data from space-borne assets, could provide societal and economic benefits through implementation at the local authority level. Expected benefits include an increase in average speed through the road network, through improved congestion management, and an improvement in key air quality indicators such as exceeding regulatory limits for PM10 and nitrogen dioxide.

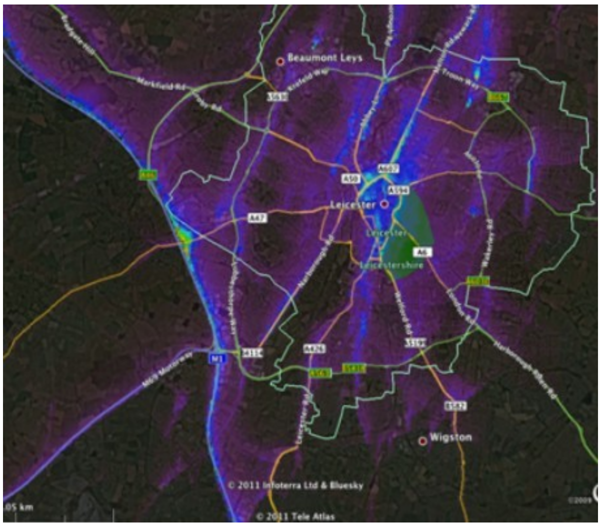

Figure 1 The Leicester road network, overlaid with air quality data produced by the AirViro model. The region of interest for the iTRAQ pilot study is shown in green.

3. Sustainable Airport development Decision Support Systems

As a hub of multiple traffic modes, an airport usually attracts heavy traffic of aircrafts, vehicles and trains. The noise and emissions produced by the traffic raises a serious environment challenge for the adjacent residence. A sustainable airport development has to consider the potential impact of any planned increment of runway capacity, terminal capacity and flight operations. Computer simulation provides a feasible way to check different scenarios before the costive investment. There have been many models in use, such as SIMMOD, INM and EDMS etc. However, an integrated model combining flight operation together with noise and emission models is preferred in evaluating long term airport development. In this EPSRC project, a pyramid structure in evaluating sustainability is put forward [1] and a prototype [2-4] is developed where flight operations, noise and emissions are combined together as one model. Different from others models which are established based on a standard airport with restricted weather and terrain condition, our model adopt computational intelligence to localise the model into a model reflecting the local conditions. Both GIS and neural networks are integrated into the model where neural networks trained with individual airport data are applied to map noise and pollutions distribution. A user friendly 3D computer aided airport design interface is also included as part of the system where 3D trajectories can be easily modified. A sample test against real world data has proved its feasibility in comparison with standard models for real world airports [5,6].
Considering our experience in developing these models, any collaboration in modelling transport pollution is welcome.

4. Multi Variable Data Analysis usinfg CI - Logistics & Passenger Information Systems

4.1 Logisitics

Logistics management presents a complex problem for system designers. CCI have successfully applied Neural Networks to road based logistics scenarios, offering superior solutions to traditional algorithmic methods.

Deliveries and pickups of goods from distributions centres to customers is a problem faced by all retailers on a daily basis. Finding real time and high quality routes that can accommodate uncertainties in the data offer significant savings and provides more environmental friendly solutions. Our approach in providing solutions to this problem focus on finding high quality solutions in real time using optimisation methods and methods of artificial intelligence and can tackle cases with mix fleets, deliveries with time windows, mix delivery and pickups and many other variants of this problem.

We also apply this problem to other application areas including waste collection and dial-a ride.

4.2 Passenger Information Services

CI is equally applicable to the analysis of data for use in passenger information services, and good example being our information system for the quality of aerial transportation

This project aimed at building an artificial intelligence based observatory of the quality of Spanish aerial transportation. Including the production of a ranking of airline companies to help customer s plan their journeys, and to help companies improve services. Objective/quantitative criteria (prices, timetable, punctuality, etc.) and subjective/qualitative criteria based on customer opinions (collected via questionnaires) were presented on websites for users to review. Complementing the ranking of airlines, an advisory system was developed comparing services according to their profile, characteristics of companies and also on opinions previously obtained on such services by other users.

4.3 Data Mining evidence to support hydrogen fuel cell vehicles

30 Hydrogen Fuel Cell vehicles will be trialled in Leicester in partnership with Riversimple and Leicester City Council from 2012. CCI will equip the vehicles with sensors, including GNSS location, occupancy, weight and a connection to the vehicles CAN network. The ethos being that the technology is proven; what requires examination are the economic and environmental impact of using low carbon vehicles in a City. CCI will apply data mining techniques to analyse the live data captured from the vehicle sensors, the vehicle's CAN network, and subjective information provided by the users. The outcome will be a business model to support low carbon vehicles.

4.4 Environmental Impact Analysis

The application of neural networks by DeMontfort Universities CCI Staff in transport & Engineering

In transport and environment engineering, we have been involved with both EU and EPSRC research projects. H-Sense is an EU project under FP4 Transport , and we developed the core software linking artificial neural networks with Geographical Information Systems [7]. The system had been applied in H-Sense for sedimentology prediction in the harbours of Göteborg (Sweden), Bergen (Norway) and Ventspils (Latvia) [8] . In addition to the harbour environment, we have also applied Computational Intelligence in support of airport environment management and planning in an EPSRC project [9]. Based on in-situ monitoring data of air traffic movements, its corresponding noise and emissions at Manchester airport, we developed a model to evaluate airport sustainability under different development strategies [10]. The model provides a CAD facility to construct airport runway, taxiway and terminals and to manage flights and their trajectories so as to reduce noise and emission exposure of nearny residential areas. In this model, neural networks are employed to map the planned flight trajectories and frequency into noise disturbance and emissions. Our simulation results show that the model based on Computational Intelligence could produce a better prediction than standard models such as INM in a specific airport [11]. In this research, we also proposed the pyramid hierarchical architecture for evaluating sustainability of a complex system like transport where interests from different stakeholders have to be balanced [12].

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5 VenueSim

VenueSim is a spin-out from De Montfort University (DMU), Leicester, UK. It has developed a unique software proposition that can model customer behaviour using Artificial Intelligence (AI). Areas where the modelling of consumer behaviour is now possible are in large venues such as shopping centres, transport termini and event arenas. Our software moves from basic forecasting tool to an operational planning tool. Being able to assess where consumers go once they enter a large venue such as a shopping centre and knowing on average how long they remain in certain areas, allows users of the system to more accurately assess how to plan the layout and retail tenant mix of those areas. In shopping centres knowing the time spent in certain areas allows rent levels to be adjusted to reflect dwell time and passing trade, etc.

The VenueSim products are based on a SaaS (Software as a Service) principle. Its unique proposition is that it only uses information that is currently held on the client site and no additional hardware is required. As a result the developed model is unique to that venue site and is able to accurately forecast consumer movement based on currently available data.

In airports, the VenueSim Q-Alert product is a unique software analysis and reporting tool that allows airport operators to forecast (weeks and months in advance) the flows of passengers through their airports and identify which factors will most affect these flows. The area that this has most impact is the security zone where flow is most noticeably affected. By predicting when passengers will arrive at security an airport is able to optimise the security resources required to meet this demand and get passengers into the departure lounge as efficiently as possible. This in turn improves customer service and helps to maintain security SLAs.

Retail is the major profit generator at most airports around the world as airlines drive down the landing fees to cater for cheaper air travel. However the increased queues at the security gate has slowed the flow of passengers and significantly reduced the dwell time (time spent) in the departure lounge.

As retail spend is directly proportional to dwell time the result is a marked reduction in the level of retail revenues and therefore profit generated. It has been estimated that airports lose 34p profit for every 10 minutes that a passenger spends queuing in the security area. An airport therefore has the opportunity to generate between £80k and £170k extra profit per annum for every 1 minute reduction in the time spent queuing in security depending on the size of the airport.

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