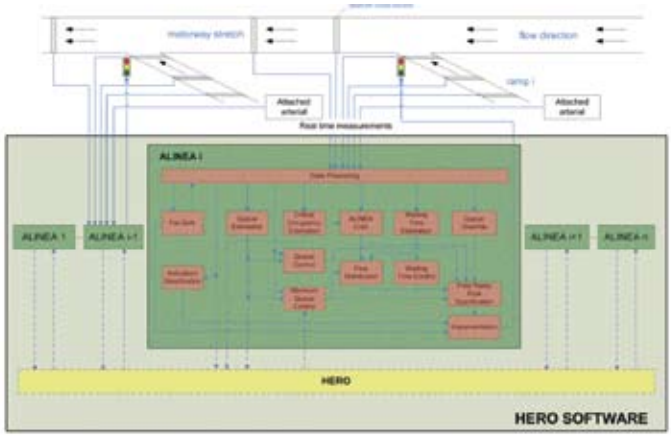
Coordinated Ramp Metering for Freeways

Freeways were originally conceived to provide virtually unlimited mobility to road users. However, the continuous increase in car ownership and demand has led to a steady increase (in space and time) of recurrent and nonrecurrent freeway congestion, particularly within and around metropolitan areas. Freeway congestion causes excessive delays, increases fuel consumption and environmental pollution, and deteriorates traffic safety.

Ramp metering, the most direct and efficient way to control freeway networks, aims at improving traffic conditions by appropriately regulating inflow from the on-ramps to the freeway mainstream. Coordinated ramp-metering strategies make use of measurements from a freeway network to control all metered ramps included therein. A new traffic-responsive feedback control strategy that coordinates local ramp-metering actions for freeway networks was developed by Prof. Markos Papageorgiou and Dr. Ioannis Papamichail at the Dynamic Systems and Simulation Laboratory of the Technical University of Crete, Greece. The proposed coordination scheme is named HERO (HEuristic Ramp metering coordination) and has been extensively tested via simulation as well as in field implementations. The developers are the recipients of the 2010 IEEE CSS Transition to Practice Award, a prize awarded by the IEEE Control Systems Society to recognize outstanding university-industry collaboration that enables the transition of control and systems theory to practical industrial or commercial systems.

Solution Overview

HERO is simple and utterly reactive, that is, based on readily available real-time measurements, without the need for real-time model calculations or external disturbance prediction. HERO is modular in structure and includes many interacting and cooperating feedback control loops (such as mainstream occupancy control, ramp queue-length control, waiting time control) as well as two Kalman filters for estimation of ramp queue length and mainstream critical occupancy. Generic software has been developed that implements the HERO coordination scheme for any freeway network via suitable input configuration.



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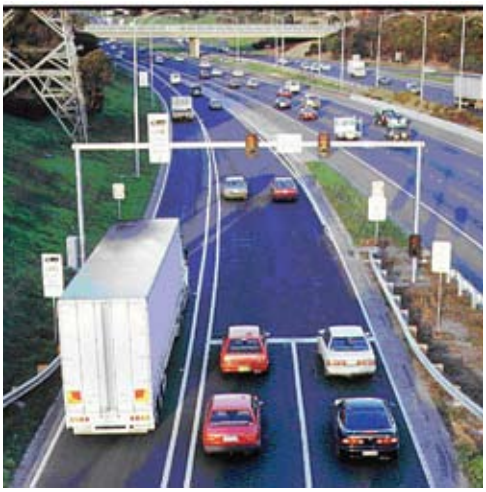


Field Application at the Monash Freeway, Australia

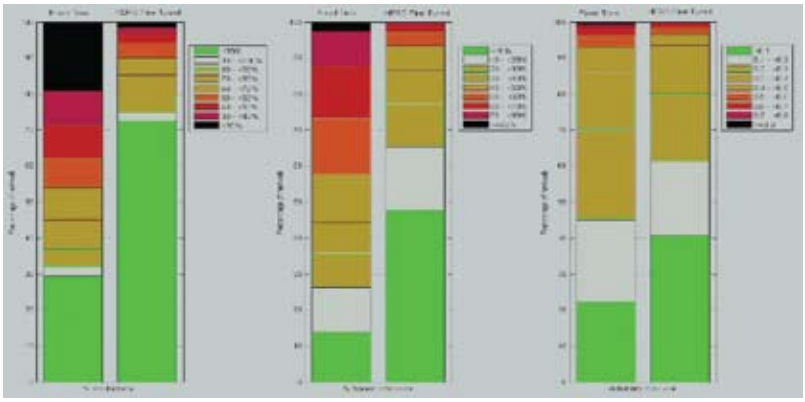
Since 2000, Melbourne's freeways have become heavily congested with extended periods of flow breakdown. The Monash Freeway, a six-lane dual carriageway that carries in excess of 160,000 vehicles per day, of which up to 20% are commercial vehicles, experiences long periods of congestion lasting between 3 and 8 hours a day.

To address this congestion problem, in early 2008 the responsible road authority, VicRoads, implemented HERO at six consecutive inbound on-ramps of the Monash Freeway. This $1M (Australian) pilot project was part of the Monash-CityLink-West Gate (MCW) upgrade and received two 2009 Victorian Engineering Excellence Awards, one for Technology and one for Engineering Innovation (http://veea09.realviewtechnologies.com). Significant benefits were demonstrated over the previous metering policy. The control logic has proven to be robust and transparent to traffic engineers. Transition to HERO has been seamless to motorists and provides significant flexibility and capability to operate the freeway close to optimal conditions. The pilot project economic payback period was just 11 days. The successful implementation and evaluation of HERO has led to its rollout during 2009/2010 at 63 sites across the entire 75-km route of the MCW upgrade project.

An evaluation of HERO's field performance was undertaken by VicRoads. HERO sensibly reduced the space-time extent of freeway traffic flow breakdown and provided significant improvements in throughput and travel speed. The a.m. peak evaluation revealed a 4.7% increase in average flow (over the previous system) and a 24.5% increase in average speed, whereas the p.m. peak evaluation showed an 8.4% increase in average flow and a 58.6% increase in average speed.

Other Field Applications

HERO was also field-implemented in a 20-km stretch of the inbound A6 freeway in the south of Paris, France, in 2006, albeit in simplified form due to lack of real-time on-ramp data in the control center. Nevertheless, results indicated a clear improvement over the existing system. In addition, HERO has been adopted for field implementation at the urban on-ramps of the A10 ring-road around Amsterdam by the responsible road authority (Rijkswaterstaat); the related implementation work should start soon. Several authorities in North America and Australia have expressed interest in adopting HERO for their freeway networks as well.



Results from the HERO implementation on the Monash Freeway using Austroads National Performance Indicators (ANPI). Three indicators are shown, with side-by-side before-and-after comparisons for each. Left to right, the indicators are: productivity (a combination of high speed and high volume on the freeway), mean speed deviation from the posted speed limit, and reliability (reflecting travel time differences from day to day).

For further information: I. Papamichail and M. Papageorgiou, Traffic-responsive linked ramp-metering control, IEEE Transactions on Intelligent Transportation Systems, vol. 9, pp. 111–121, 2008; I. Papamichail, et al., HERO coordinated ramp metering implemented at the Monash Freeway, Proc. 89th Transportation Research Board Annual Meeting, Washington, D.C., 2010.