The Influence of a New Signal Offset Optimiser on Travel Reliability and Drivers' Route Choices

(INSTInCt)

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ABSTRACT: This PhD study sets out to develop a new algorithm that will better estimate and adjust offset plans in an adaptive signal controller such as SCATS (Sydney Coordinated Adaptive Traffic System) and other proprietary UTMC software. Furthermore, the effect of this new optimiser will be studied in the context of its effect on route travel reliability and its influence on drivers‟ route choices during congested and non- congested periods. The study will investigate in detail how drivers' process and act on the visual cues when approaching signalised intersections, and how they apply this visual information to unplanned short-term decisions that result in lane changes, and ultimately route changes at the next intersection due to observing queue and/or traffic signal light changes or states. Anecdotal and empirical evidence support that drivers sometimes make these snap decisions on route choices on approach to a signal, contrary to following their habitual or pre-planned path. Gross route choices are significantly influenced by drivers' network familiarity and experience. This study hypothesis is set to determine optimising techniques that have a significant effect in manipulating driver behaviour using signal states and other visual cues. The study will utilise both simulated and live traffic conditions to study the effects.

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Introduction

The proposed study has two distinct components that will blend the disciplines of engineering and psychology with respect to vehicle drivers in an urban network. From an engineering perspective it sets out to develop a new algorithm that will better estimate and adjust offset plans in an adaptive signal controller using SCATS (Sydney Coordinated Adaptive Traffic System) or other proprietary urban traffic control (UTMC) software. Furthermore, from a human behavioural perspective, the effect of this new optimiser will be studied in the context of its effect on drivers' perception of route travel time reliability, measured by the influence of queues, and traffic signal states, on their lane and route choices during congested and non-congested periods.

The current practice when optimising SCATS systems is to manually estimate the *offset* values between signals, often by use of an arbitrary average or constant travel speed over a link to estimate when a platoon of vehicles would arrive at a downstream signal. The offset is the lag in time between the upstream green phase and successive green phases along a route to achieve continuous flow conditions.

On-site observations are seldom undertaken more frequently than on a three year cycle, and these observations are of doubtful statistical significance to determining the variability of traffic conditions during the peak and shoulder-peak periods for the offset to be meaningful applied.

A further component to this research will address the driver's response to the approaching signal state, the effect of the diver's prediction of queue formation and dissipation, the mid-link behaviour between followers and putative platoon leaders whilst approaching a signal, and how these factors influence driver's behaviour in terms of lane changes and on-the-fly route choice changes. This requires a deeper understanding of how a driver's eye fixates on the unfolding scene, the perception of the visual stimuli so observed, the processing of the information via cognition, and consequent actions taken by the driver.

Not only does this research have a practical outcome in optimising a UTMC system, but it also will contribute to our knowledge of how we model traffic and driver behaviour on an aggregate and disaggregate level. It has the further potential to better understand how we as traffic engineers can potentially manipulate driver behaviour through a more in-depth understanding of the visual cues that the drivers react upon.

Objectives

The objectives of this research set out to:

- improve optimisation and management of traffic systems through active and passive signal management techniques
- utilise the existing loop configuration at the stopline in the traffic system, without the need for installing additional detector loops
- develop a new offset algorithm that predicts likely queue states and considers platoon dispersion variability at every cycle
- improve our understanding of how drivers use visual cues in making decisions at signalised intersections
- better understand the underlying factors and influences that drivers apply during their lane changing and route changing decisions during congestion and under-saturated conditions
- provide new variables for modelling lane changing and route choices in modelling software

Overview of the Current State of Art

The focus of this paper is to outline the context of the engineering approach of the optimisation of the traffic signals by first understanding the psychology of driver behaviour.

Traffic Signal Management Systems: SCATS' algorithm was designed to utilise minimal vehicle detectors, being reactive, not predictive to the adjustment of its parameters, and in particular the adjustment of the offsets.

Anecdotal evidence along regular congested commuter routes under SCATS control suggests that a green wave is only maintained up to a certain level of under-saturated conditions. (This is hypothesised to be around the 75% vehicle-capacity ratio of a lane). When flows approach near-saturation levels, the green wave is often impeded by the back of the discharging queues, leading to rapid oversaturated conditions on the coordinated corridor caused by queue shockwaves.

It often requires a number of cycles before SCATS begins to respond via adaptation and smoothing algorithms (usually averages loop measurements over the preceding 3 cycles) to the changing traffic conditions, causing it always to be "behind the eight ball", particularly in highly variable traffic conditions. This study sets out to improve the status quo via an automated real-time process giving it similar functionality to SCOOT with respect to predictive optimising of the offset at each cycle in a pre-emptive fashion.

Benefits: The improvement in travel efficiency for the greater Auckland region was estimated as follows:

- A direct operational benefit-cost ratio is estimated at greater than 30 with an estimated optimising labour cost saving of around $3,500 per signal if optimised manually on a 3-year cycle or around $280,000 per annum.[1]
- User benefits - Travel time saving of $10 million per annum per peak period[2].
- Fuel savings of 10 million litres per annum[3]
- Societal benefits - CO_2 reductions of 26,500 tonnes per year[3]

Route choices: Drivers' route choices and lane changing decisions are predominantly represented in prediction models as an econometric construct relying on consumer behaviour theory, which is better suited to explain human behaviour on a deterministic macroscopic level. However, at the stochastic microsimulation level of driver behaviour, it is represented using empirically derived behaviour models modified with stochastic sampling of awareness and aggressiveness of driver and vehicle behaviour. These variables modify the acceleration/deceleration and lane changing decisions of the simulated vehicle.

Smith (1979) has undertaken much research in optimising signals and also using signals to modify driver behaviour in terms of route choices. He posed the problem as*" Current signal-setting policies, such as Webster's Method (1958) or TRANSYT (Robertson, 1969) are based on the fundamental assumption that route-choices are unaffected by the signal-settings chosen. This is reasonable when route-choice is obviously and severely limited, or congestion is slight, but it is not reasonable in general. It is therefore natural to seek signal-setting policies which are optimal when route-choice decisions by drivers are taken into account."* This problem has been included in many urban traffic signal management systems, two of the most well-known are Split Signal Offset Optimising Technique (SCOOT) and Sydney Coordinated Adaptive Traffic System (SCATS).

Yang (Yang and Yagar 1995) posed the traffic signal optimisation problem as shown in figure 1

1 Assuming only 60% of all signals in Auckland can benefit from this optimiser.

2 Assuming a 3% improvement in travel time efficiency based on difference between SCOOT and SCATS gains.

3 GHD ltd. (2007) Report for Route Optimisation: Pilot Study, EECA, *Urban Transport Energy Reduction.*

below. Link 1 is an approach to a traffic signal with a queue at the intersection. Link 3 has opposing traffic flow creating delay on link 1. Approaching vehicles at node 1 can see the queue on the link ahead and must decide to change to an alternative route via link 2, or to stay on link 1 whilst travelling to node 2.

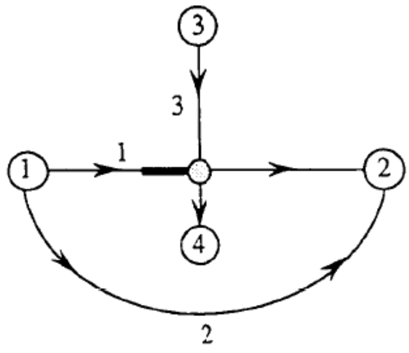

Figure 1: A Simple Example

Driver psychology: The majority of psychology research in the driver behaviour field is centred on accident prevention and particularly aimed towards driver distraction, with a small body of work focussed on wayfinding and navigation. The behavioural mechanism that applies to drivers reactions is best described in the field of psychology of perception, cognition and action. The human brain evolved a visuomotor control system to act upon the increasingly complex world, and it is this system that we need to understand before we can attempt model and predict the behavioural aspect of drivers.

The primary sensory system used by a driver is the eyes to perceive the environment. The encoded signals in turn feeds into the visual cortex located in the occipital lobe located at the rear of the brain. These in turn have projections to the other cortices via two distinct processing paths called the dorsal and ventral streams. The dorsal stream is responsible for spatial and temporal locations of objects, and the ventral stream for object recognition. All other sensory inputs are processed and then combined in other distinct parts of the brain, which then through cognition is translated into a coordinated motor control action to the muscles. The actions have both feedforward and feedback mechanism using inputs from the cortical, nervous and sensory system to make further adjustments to the initial action. It is through understanding of this complex mechanism that we begin to understand how humans can perceive and act upon the world sometimes quite differently from others, given a set of identical circumstances.

With the eyes as the primary sensory input, it is critical to understand how the visual input system works. Research applicable to understand driver eye movements, memory and actions have explored the effects of “highway hypnosis”(Williams 1963) or “driving without attention mode” (DWAM). Karrer (Karrer, Briest et al. 2004) gives a literature review of the phenomenon of Highway Hypnosis, Driving without Attention Mode or Time Gap Experience.

Highway hypnosis was used to describe the trance like state of a driver during long monotonous journeys that induce short lapses of attention, but yet remain awake and driving error free. Kerr (1991) described a new term “driving without attention”, and describes this as how drivers are seemingly unaware of their driving errors even with their eyes open. He describes the “time gap experience” is described as “*of failing to remember what has happened on the road during a longer time interval”.*

However, in the context of lane changing and route decisions the anecdotal evidence confirms the same phenomena exists in our own driving behaviour such as instances when we cannot recall the route or traffic signal states recently traversed, yet we are able to drive safely along the route arriving at our destination without incident. It is postulated that whether this state also would encompass the so-called “driving on auto-pilot” state when a driver heading towards a destination similar to a regularly used route, and then out of habit or inattention arrives at the wrong destination, i.e. going to the city to shop, but then inadvertently aims for the office that is roughly along the same route, but in a significantly different location relative to the shopping destination.

A further aspect of snap decision-making is to understand the mechanism behind the situation described below and to determine if this action, or reaction, is similar to when making lane and route changes on the approach to a signal with a significant queue present. The presence of the queue being hypothesised to affect the ability of receiving a green phase once the stopline being reached, or indicates that unusual congestion is present ahead and an available alternative route may be judged to be more favourable now.

> *I have often both experienced and observed other drivers, when stationary at a traffic light for some time and staring what is maybe blankly into space, that a signal change causes an immediate reaction to accelerate before confirming the actual signal state is applicable to their intended movement. The human visual field can be broken down into the foveal vision (central 2 ˚), the parafoveal (extends 3˚ either side of the fovea) or peripheral field (about 100˚ either side from the central field). False starts typically occur when adjacent vehicles begin moving, or when the signal light change is in the parafoveal or peripheral visual field.*

Given that humans are often only able to react correctly on visual inputs via eye fixations, the movement of the eyes are an important consideration to explore in more depth.

Galpin’s (2009) review of the literature found that the paradigm of change blindness (the inability of detecting changes in the visual field during saccades) being applicable to the driving task. Previous research found that due to the dynamic nature of driving that the frequency of saccades (the eye movement between fixations) increase, thus changes during saccades are very pertinent. This may prove to be useful to consider when a traffic light (phase) change occurs ahead of the approaching driver, who then changes direction before fixating on the actual traffic light. It is hypothesised that the presence of an expected, or unusual queue, may induce different driver behaviours, given our understanding of how differently novice and experienced drivers focus on the road environment.

Mourant (1970) research found that search and scan patterns verified that the peripheral area of the eye is used for monitoring lane position, other vehicles, and road signs so that the fovea may be directed for a closer examination when the situation demands it. A subsequent paper by Mourant (1972) found differences between novice and experienced drivers, with novice drivers concentrated their eye fixations in smaller areas, looked closer in front of their vehicle, sampled their mirrors less and made pursuit eye movements as opposed to fixations of the more experienced drivers. Experienced drivers apparently use their peripheral vision for monitoring lane position and novice drivers use their foveal vision.

Car Following: Brackstone (2009) *“Despite the recent surge in both simulation modelling and Intelligent Transport Systems (ITS) for motorway and vehicle applications, a lack of detailed understanding of how traffic conditions affect driver behaviour still exists.”*

Brackstone found no evidence that the road type itself may have an effect on following behaviour, for example, the frequent stop and start nature of traffic occurring on urban roads, interactions with merging vehicles, traffic control systems such as traffic signals, the presence of pedestrians and a wider range of road users may necessitate a higher degree of preparedness. An important aspect was that Brackstone ignored behaviour when in immediate proximity to traffic signals, with the driver having to consider whether to ‘stop’ or ‘go’ should the signals begin to change from green to red. He thought it was likely to affect behaviour for only a small period of time, while the driver is close to the junction, and suggested the behaviour will probably be identical to other effects such as queuing. This is maybe an oversight in his approach as he may have missed an interaction effect as he discounted this out of hand without evidence.

Lane Changing: In a series of studies, McDonald (1980) and colleagues used steering wheel reversal rate (SRR) *“ is not a simple function of secondary task demand but rather involves a fairly* *complex relationship between primary task demand, secondary task demands, driver characteristics and the effort invested in the different tasks".*

Brackstone (2003) found on motorways drivers changed lanes about every 4-5 km under high flow conditions. In urban conditions this occurs far more frequently due to intersection spacing, lane allocations, the lane flares at approach to intersections and lane merges downstream of this.

Methodology

Data Collection: Mourant (1970) found that *"the visual task in driving may be described as the monitoring of a continuous stream of information through which the vehicle is travelling. At a given instance the foveal (central) region of the eye examines only a 2° area of this stream. Much more of the information is sensed through the peripheral portions of the eye.*

From the review of the literature describing driver awareness and visual fixations the various measurement and data collection techniques may have merit in adopting to understand the following phenomena:

- What do drivers fixate on when approaching traffic signals in different levels of congestion?
- Are drivers consciously aware of the traffic signal state and queue formation before they make lane and routing decisions?
- Where do drivers focus when they make the routing change, and do they only fixate on the traffic signal state to confirm a lane change manoeuvre was the right choice due to an actual or anticipated red signal state?

The type of data to be analysed will include:

- Synchronised traffic signal and queue states during intersection approach
- Record of surrounding traffic environment, forward visibility, static and dynamic objects
- Driver eye fixation correlated with level of awareness and simultaneous action, i.e. steering and velocity changes
- Driver eye tracking movement to determine the relationship of fixations, saccades and the changing signal state.

Simulators and field observations: Brackstone (2009) found that a comparison between the simulator and field results showed the field results are consistent with the results obtained in the simulators. However, an apparent difference was that the physiological workload and steering activity was higher in the field given the increased effort required due to the higher actual risk in real traffic. He warns that the results of car-following behaviour should be treated with caution due to the established limitations of simulators in presenting the driver with a realistic picture of a congested road.

Four sites have been selected across Auckland that comprises of parallel routes between arterial road systems. These sites will be used for both in-car, field and simulated trials using both SATURN and PARAMICS software. Trials will be undertaken to study the effect of before and after optimised states.

Other data collection devices such as driver simulators, eye tracking and cardio recording devices are being investigated for use with this research. For the live field trials an instrumented vehicle fitted with synchronised telemetry to record velocity and angular changes, video and eye tracking devices capable of detecting the forward and peripheral field of the driver with technology to discriminate the area of foveal focus relative the traffic signal state and vehicle queues ahead. The driver will be fitted with cardio recording devices to capture cardiac activity to determine the synchronicity between foveal focus, steering and velocity change. The response to be detected is whether the foveal focus and resultant action is a cognitive awareness of changed traffic state that would manifest itself as active or possibly passive workload, i.e. cognitive reaction or automated/habitual reaction.

Conclusion

A PhD research study sets out to improve efficiency in a traffic signal system that utilises minimal vehicle detectors and to better understand the impact on driver behaviour in congested and non-congested traffic states.

- Understanding the driver behaviour within this context is critical to being able to develop driver predictive models that interact with urban traffic systems
- The outcome of the study has a number of advantages in terms of travel efficiency gains, environmental and societal benefits
- It will enhance our ability to improve traffic management techniques using signal states and other visual cues
- It will lead to an improved understanding of driver behavioural factors in lane changing and route choice changes that could be used to improve our forecasting accuracy in traffic models

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