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Project Summary Report 0-4729-S
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Project 0-4729: Reducing Traffic Congestion and Fuel Emission through a Minimal Cost, Self-Tuning Closed-Loop Progression System

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PROJECT SUMMARY REPORT

PILOT 05—Pattern Identification Logic for Offset Tuning

Researchers in the traffic control field have invested extensive efforts in the development of adaptive control software (ACS) over the last few decades. This adaptive control software is based on applying specific proprietary software to a signal control system. ACS has several advantages over traditional control systems since it can model and track individual vehicles on a second-by-second basis. ACS is not bound by traditional control parameters such as cycles, splits, and offsets. Rather, ACS optimizes green duration and phase sequencing in real time, providing the most optimal control of traffic signals.

ACS, however, typically requires an extensive input of system parameters for favoring individual movements plus a large number of vehicle detectors to collect movement-specific traffic data. A major drawback of these systems is the extensive effort required for training personnel on new proprietary architecture.

On a parallel track, the private sector has developed closed-loop systems that are operated by coordinated-actuated controllers. A closed-loop system consists of a master traffic signal controller connected to a series of traffic signal controllers using hard-wired connections, fiber-optic cables, or spread-spectrum radio. The on-street master supervises the individual intersection controllers and issues commands to implement timing plans stored in the local controllers. The master controller can also report detailed information back to a traffic management center using a dialup telephone or similar communications channel for monitoring purposes.

Closed-loop systems provide actuated control capabilities through their ability to respond to cycle-by-cycle variation in traffic demand while still being able to maintain progression for arterial movement. These systems are widely implemented in Texas on arterials to provide efficient operation of arterial intersections while maintaining arterial progression. Nevertheless, poor progression can be observed along most arterials due to outdated offsets, short-term variations in traffic patterns (early-return-to-green), or changes in arterial speed and traffic volumes and waiting queues.

The objective of this project was to develop and test an algorithm that automatically fine-tunes offsets in real time in response to changes in traffic patterns measured at an upstream detector. Such an algorithm would be able to reduce traffic congestion and fuel emission by minimizing vehicle stops and delays at arterial intersections.

What We Did...

ACS has great potential to provide the most optimal control of traffic signals. However, ACS comes with a high price both in terms of initial system cost and in operation and maintenance cost. Closed-loop systems operated with a traffic-responsive plan selection mode (TRPS) come closest to providing the benefits of ACS, and those systems far exceed the performance of closed-loop systems operated with outdated timing plans with time-of-day mode (TOD). Both adaptive control software and closed-loop systems have inherent limitations: assumptions about travel time and platoon dispersion characteristics.

Previous research has introduced an innovative "at-the-source" (ATS) method to adaptively fine-tune offsets in real time. The ATS method does not suffer from the limitations associated with assumptions about travel time and platoon dispersion characteristics. Augmenting the control strategy with an ATS algorithm can greatly increase the net benefit of a control strategy. This approach is illustrated in Figure 1. The algorithm developed in this project addresses the most critical limitation of previous efforts in this area.

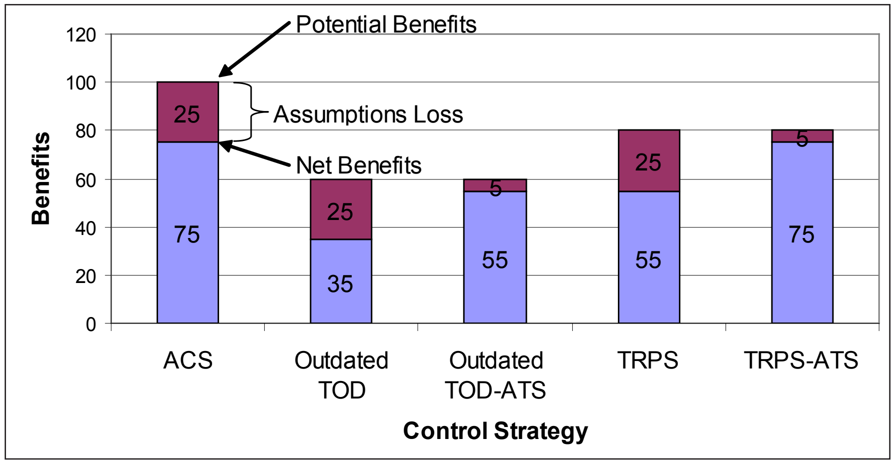

Figure 1. Research Approach.

Offset Classification

In order to increase the stability and robustness of the offset classification algorithm, researchers conducted a simulation experiment to obtain representative data points for detector actuations for each of the offset cases examined. CORSIM simulation was used to represent a network of two signals. Analysis of the simulation output determined the optimum offset with the least number of vehicle stops. All other offsets were then expressed as their deviation value from the optimum offset. Different statistical parameter calculations used the count profile (count values every 5 seconds of the cycle, plotted versus time in cycle) obtained from an advance detector upstream of the signal.

The objectives of the simulation were to find the best parameters that can be used to distinguish optimum offsets from sub-optimum ones and to be able to classify offsets into optimum and sub-optimum groups. However, stability of the classification algorithm was a major requirement. In order to avoid excessive controller transitioning, offset improvements needed to be made in small increments.

Figure 2 shows a plot of the count profile median versus the offset group. Each group was represented with eight cycle profiles. It was clear from the results that groups 3, 4, and 5 could be classified with each other. Those groups were clearly delineated from groups 1 and 2. However, groups 1 and 2 were not easily delineated from each other. It was therefore necessary to supplement this parameter with additional parameters for further recognition.

The second parameter used was count profile skewness. Figure 3 shows a plot of the profile skewness versus the offset group. Note that groups 1 and 2 are easily distinguished from each other. Although groups 4 and 5 are not well differentiated using this parameter, supplementing the information from the first parameter is sufficient for complete recognition of the five groups.

PILOT 05 Lab Setup

The identification logic was implemented in a distributed architecture system installed in the TransLink® laboratory at the Texas Transportation Institute (TTI). The prototype lab installation of PILOT 05 utilizes a digital I/O module of the microcontroller to interface with the cabinet's back panel and to monitor in real time:

- phase indications;
- stop bar and algorithm detectors' occupancy and count profile;
- current plan's cycle, splits, and offset; and
- phase durations.

For cabinets equipped with a National Transportation Communication for ITS Protocol (NTCIP)–compliant traffic controller, the microcontroller

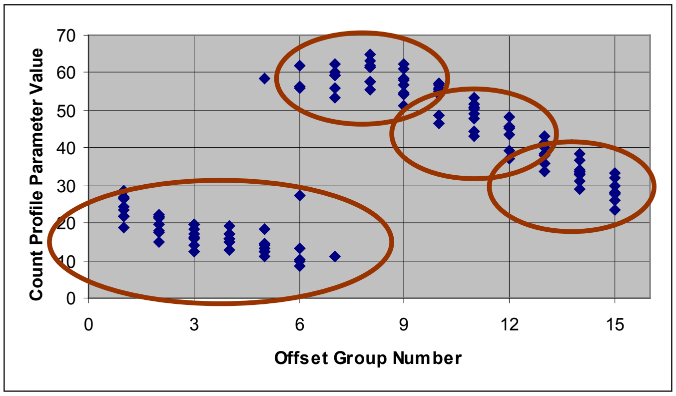

Figure 2. Median Count Profile Recognition.

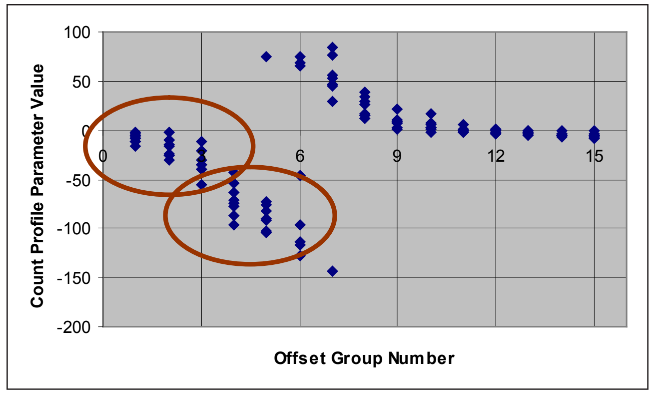

Figure 3. Skewness Count Profile Recognition.

collects the required data by exchanging NTCIP-standard messages with the controller over an RS-232 serial port. The slave subsystem collects the counts and occupancy of the algorithm detectors in periods of X seconds, where X is specified by the user. At the end of each cycle, the slave algorithm calculates the occupancy and count profiles for the algorithm detectors over the cycle length and sends a message with the information to the master system. Figure 4 shows a master subsystem installed in the TransLink® lab for algorithm evaluation and testing.

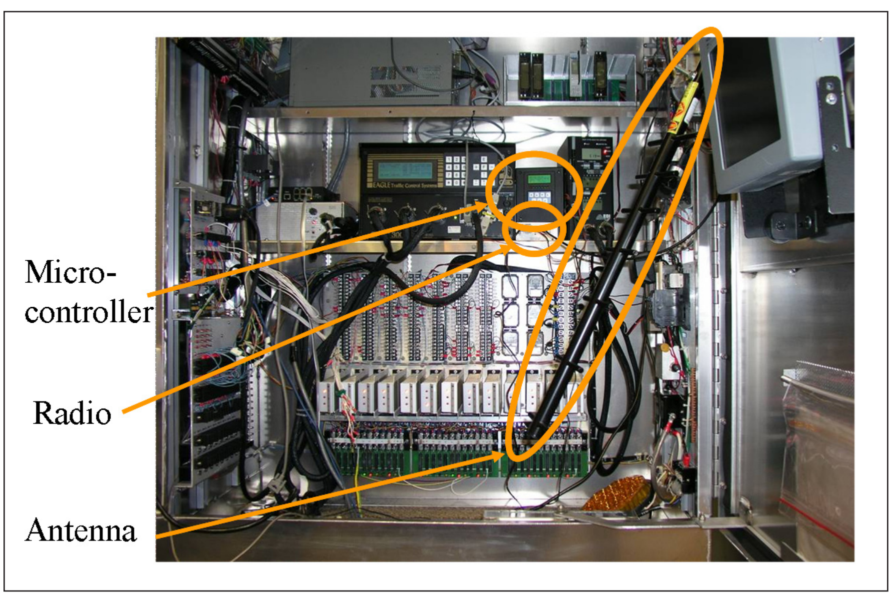

Figure 4. TransLink® Lab Pilot 05 Master Subsystem.

What We Found...

Augmenting commonly installed closed-loop systems with the abilities of adaptive control software dramatically improves system performance.

This project developed a flexible experimental framework for theoretical development and experimentation of adaptive control algorithms, in the context of closed-loop systems operation. The developed system includes:

- robust classification algorithm of progression quality and remedies, and
- vendor-independent distributed implementation architecture for the proposed algorithm.

PILOT 05 addresses some of the major limitations identified by previous research in this area. System specifications are included in the appendix of the comprehensive research report for this project (Report 0-4729-2) to facilitate vendor implementation of the system.

The Researchers Recommend...

The researchers recommend further investigation of NTCIP communication protocol compliance and integration with TRPS features. The researchers also recommend coordinating development and improvement of ATS technology with ACS-Lite efforts by seeking the active involvement of the Federal Highway Administration.
In addition, the researchers recommend the following future research:

- development of a proactive module for PILOT 05 to predict future demand and
- integration of an improved TRPS control mechanism with the PILOT 05 structure and algorithm.

For More Details...

Research is documented in Report 0-4729-2, *Distributed Architecture and Algorithm for Robust Real-Time Progression Evaluation and Improvement.*

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