

## SIMULATED REAL-TIME INTERSECTION SIGNAL CONTROL

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### ABSTRACT

This paper describes an experiment applying Artificial Intelligence and Expert Systems design to simulate signalized intersection control. The system applies traffic engineer's heuristic control strategies on the IBM PC/XT/AT based microcomputers. This study examines the feasible approaches in automating the intersection signal control for efficient operation. Essentially, a one-intersection simulated signal control environment has been constructed through two interconnected IBM PC/XT/AT, or compatible microcomputers, which automatically examine the proper actions needed to handle the variable, synthetic input traffic demands. This advanced microcomputer-aided design can also be expanded in the future for other real-time systems to monitor and control current and predicted traffic conditions.

### 1. INTRODUCTION

More than half of all the vehicular trips and vehicular mileage take place in urbanized areas. Currently, most metropolitan areas in the United States are encountering urban traffic problems. Urban traffic control strategies, such as providing effective signalized intersection control and traffic congestion management in the oversaturated highway networks, can be optimized through experienced engineering designs before the actual field implementation (ITE, 1985). However, the most appropriate control measures for the given conditions are often difficult to determine. To complicate the overcongested urban usage situation further, new traffic control measures involving new computer traffic control technology, vehicular communication, and control technology are expected to emerge in the next decade (FHWA, 1985).

For years, transportation professionals have used computers to assist them in providing traffic analysis, transportation planning, signal timing, of alternative traffic management techniques evaluation (FHWA, 1982). Spontaneous response traffic management strategies and decision support tools are needed for efficient traffic management. The Artificial Intelligence and Expert Systems Design (AI/ES), being introduced successfully in many disciplinary areas, can be applied to assist transportation professionals to provide heuristic human knowledge to solve the growing urban congestion management problems. There is a critical need for examining existing methodologies to determine whether these control techniques can be implemented through Expert Systems design.

This study was to develop a microcomputer based intersection signal environment, as shown in Figure 1, which simulates the implementation of traffic engineer knowledge-based control using Artificial Intelligence techniques and Expert Systems designs. The system was developed to examine the applications of Artificial Intelligence/Expert System (AI/ES) techniques on automatic traffic signal control. A simulated signal control environment was constructed to evaluate the operational effects, and examine different object-oriented signal control strategies on the system operational performance of the synthetic signalized intersection (Gartner, 1985).

### 2. REAL-TIME TRAFFIC CONTROL

Over the years, many transportation agencies have developed and implemented different real-time, closed-loop, microcomputer-based traffic control systems (TE&C, 1985). Actuated controllers and traffic responsive systems have increasingly been increasingly installed. However, there is an urgent

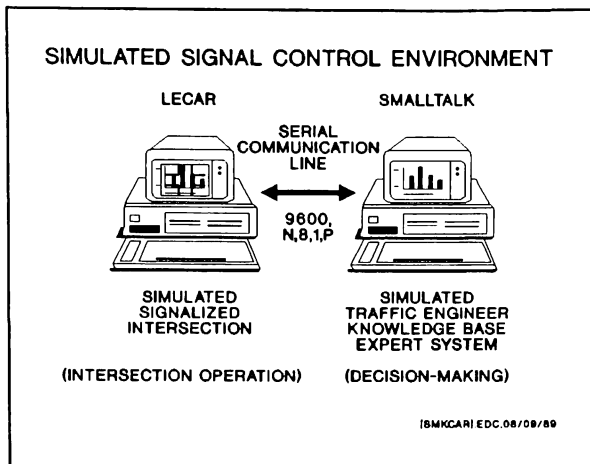


Figure 1: Simulated Signal Control.

need to develop a simulated arterial signal control system for assisting engineers in the control strategies (ITE, 1985). Design policies and operating procedures are also needed to assist users in developing the system detection design and control strategies to take advantage of the available computerized control systems. In particular, traffic engineers in the 1990's can take advantage of the emerging microcomputer technologies to improve coordinated signal operations. Responsive strategies and decision-making supports can be developed to automatically monitor and analyze changing traffic demands. However, the successful signal controls require effective selection of microcomputers and responsive controllers, proper traffic plans, coordination systems, system control strategies, and intersection signal patterns (TE&C, 1979).

An off-line, training system can assist engineers in evaluating and understanding existing and proposed control strategies. Implementation of evaluation procedures within the expert system can support traffic responsive computer systems in evaluating traffic patterns. The system can utilize traffic inputs from arterial systems; examine alternative scenarios; evaluate off-line strategies based on operational policies identified; and recommend appropriate actions. The use of off-line, graphics-based, simulated evaluation system can further allow users to examine off-line control databases, evaluate possible strategies, analyze

alternatives, maintain control records, and assist engineers in understanding the on-line signal control pattern selection processes (Gartner, 1983).

Many researchers are constantly searching for new approaches to computerize traffic operations and highway design which can take advantage of the emerging technology. As part of "Advanced Interactive Traffic Analysis Concept", this study is developing an off-Line, graphics-based microcomputer analysis system to assist in the design and evaluation of actuated intersection detectors and arterial system detector configurations. The study will apply graphics-based Computer-Aid Design (CAD) and Expert System (AI/ES) techniques for improving actuated traffic signal detector designs and operations. This study has developed an interactive design system to evaluate different detector layouts and automate the detection system design. The system can also be used to optimize potential locations, system detector layouts, and system configurations for principal arterial systems. The study will be able to evaluate the off-line, real-time, time-dependent arterial signal system traffic volume to optimize the planning and design process of detector layouts, display recommended optimal system detector locations, and suggest the flexible arterial subsystem configurations. The simulated system can integrate the expert system based traffic control strategies, convention traffic analysis software, and the computer aided training system through the implementation of various simulated real-time traffic control.

### 3. BASIC CONCEPTS OF SMALLTALK

Smalltalk uses an object-oriented paradigm which allows for modelling systems in terms that match human thinking and language, in terms of viewing anything as objects and the associated actions on objects (DigiTalk, 1986, 1987). These actions include the classes, messages, methods, and instances to describe the interrelationships among different elements in the study system. Objects are self-describing data structures. In Smalltalk, everything is an object. Every object is an instance of a class. Classes are the program modules of Smalltalk because they describe data structures

(objects), algorithms (methods), and external interfaces (message protocol). An object possesses several characteristics. Even though every object is individualistic, each also possesses common characteristics with other, similar, objects. Several objects can be classified as a class.

All processing in Smalltalk are produced by sending **Messages** to objects. Any message can be divided into three parts; a receiver object, a message selector, and zero or more arguments. There are three types of messages, i.e., unary message, binary message, and keyword message. In addition, **Methods** are the algorithms which are performed by an object in response to receiving a message in the process. Every message has a method associated with it. The entire set of messages associated with a class is called the message protocol for that class.

There are two types of methods. The Class methods send messages to the class. The receiver is always the class object, not an instance of the class. For example, assume that Lassie := Dogs new. Lassie becomes an instance of class 'Dogs'. 'new' is a class method for class 'Dogs'. On the other hand, the instance methods send messages to instances of the class. The receiver of an instance message is always an object that is an instance of the class. For example, in the case that Lassie talks. Assume that in the class 'Dogs', we define 'talks' as an instance method. Inheritance is particularly useful in defining the relationships among different elements of the system. An object inherits all instance variables defined in its superclasses by containing the ones defined in its own class.

For example, assume that the Animal has the properties, such as name, knowledge, habitat, topspeed, color, picture, and others. In addition, the Bird can also fly, the Parrot has the capability of vocabulary, and the Penguin has some the property of the above animal. The Dog and Whale are both Mammal, however, the dog also barksAlot. Then, the parrots, penguins, dogs and whales can inherit all the common characteristics of the similar animal in addition to their specific nature. Besides the inheritance properties of all the animal using the representation of the instance variables, methods are

also inherited. When a message is sent to an object, Smalltalk looks for the corresponding method defined in the objects's class. If it finds the method, Smalltalk performs it. If it doesn't find the method, however, Smalltalk repeats the procedure in the object's superclass. This process continues all the way to class Object.

#### 4. SIMULATED INTERSECTION

As illustrated previously in Figure 1, a macroscopic, graphics-based, interactive signalized intersection simulation environment which consists of the operations of two interconnected microcomputers has been developed. The first microcomputer acts as a "Simulated Real-world Intersection" for collecting all the traffic information. The other microcomputer serves as the "Supervisor Computer" for examining information, executing control strategies, evaluating system performance, and implementing the recommended actions. The system has been developed to automatically collect the simulated traffic information, summarize the performance evaluation, provide AI/ES traffic signal control, perform system evaluation, and illustrate the operational evaluation through a real-time graphics display. This simulated system can be used to evaluate the operational efficiency of different traffic control strategies being applied under the selected control objectives (NCHRP, 1977).

A simulated intersection control environment has been designed with two interconnected IBM PC/XT/AT or compatible microcomputers with serial communication lines between the two systems. The system not only display the effects of traffic as they respond to the control setting but also examine the proper actions needed to handle the variable synthetic input traffic demands. The Oldcar program, as in Figure 2, integrated with the communication routines is tested to send and receive some information from the program written in Smalltalk/V language on another machine. Then these two programs respond and interact with each other according to the information sent and received. The Oldcar program demonstrates an intersection with an infinite number of cars coming and randomly going straight, turning right, or turning left. As

every 5 cars pass through the section, the program will send information to the other program in Smalltalk/V simulated control environment.

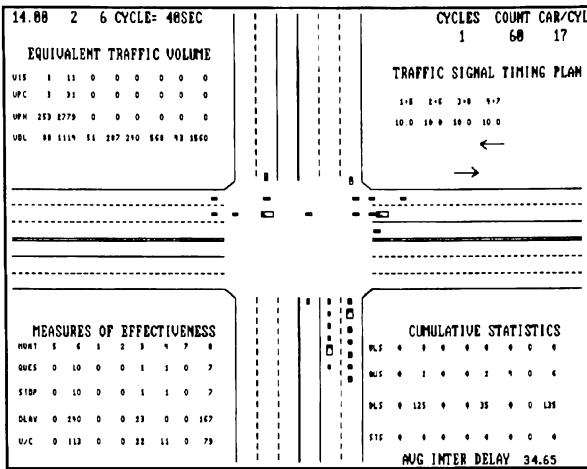


Figure 2: Intersection Graphical Display.

### 5. CONTROL ENVIRONMENT

The control environment is constructed with the Smalltalk/V program as shown in Figure 3. The environment, developed from the basic traffic engineer knowledge base, acquire information from the simulated intersection, receive onto the screen, and simultaneously evaluate the needed green splits between the main and cross street according to the demands. On the left pane of the communication window, this program displays a set of histograms indicating the number of cars going straight, turning left and turning right as every 15 cars pass through the intersection. This event will record and count how many times this same pattern happens and then, it will display the transcript every 30 events.

This case study is a simplified version of signalized interaction operations between two different microcomputer programs running on two different PCs. One program runs a simulation program while the other gets some information at certain periods of time, or requests it at any time; then, processes and displays some useful information. From the programming language point of view, a new programming language, Smalltalk/V

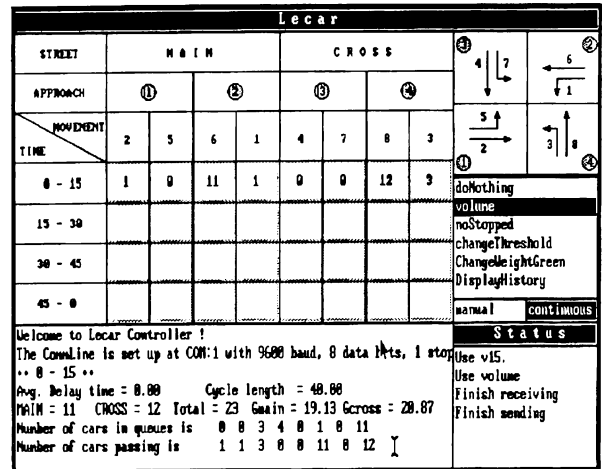


Figure 3: LECAR Controller Under SmallTalk.

was tested together with the Prolog class showing the potential use of this object-oriented programming language.

The Prolog subclass "Oldcar" is created to provide the evaluation, of traffic conditions, of using either the arriving demands passing through or the standing queues waiting at the intersection. The evaluation is based on two production rules. In the first clause, The first statement will unify the 'pattern' variable with what is returned by 'serial1 pattern' (Smalltalk/V method). Then, the second statement checks the pattern with the 'patternOccurrence' database (initialized by the Serial1-Class instance method 'initialize') if it exists or not. In case it does exist, the rest of the statements will add one to the number of occurrence and replace it back to the database using retract and asserts predicates. The second clause is executed when the 'pattern' does not exist. The clause will assert the fact, including both the pattern and its number of occurrence, into the database.

Each time the user requests the control history, the program will display a set of bar charts. In addition, the system will also invoke the Prolog method, 'accumulate', to save the pattern and count the number of occurrences. Having displayed a set of thirty bar charts, the program will use the 'Questions-Answers' characteristic of Prolog to retrieve all the solutions matching those facts in the database to be printed in the Transcript pane.

Lecar window is displayed on the screen after an expression "Lecar new openOn: (CommPort port: 1)" is evaluated from System Transcript which is a main window of Smalltalk/V environment. Lecar window provides the interface between users and the program. Lecar window displays the data received from another PC and displays the result of the calculation based on the received data. Lecar window also reads some inputs from users. Lecar window is created by method openOn: in class Lecar.

As shown in Figure 3, Lecar window is divided into 8 panes or subwindows. Each subwindow can perform different tasks as mentioned before. These panes are displayMovement, carsTable, result, method, manual, continuous, status, and do-nothing. The "DisplayMovement" pane is located at the top right corner of Lecar window. It is a GraphPane. This pane is only for displaying the movement directions of which each is assigned a number from 1 to 8. It also displays the numbers 1 to 4 which are assigned to the area where cars approach the intersection. The "CarsTable" pane is located at the top left corner of Lecar window, and it is a GraphPane. It takes about 2/3 of the area of Lecar window. This pane is for displaying the number of passing cars in each direction within every fifteen-second interval. It will show four intervals. The number of cars is the traffic demand data received from another PC running the signalized intersection simulation program.

The "Result" pane is located at the bottom left corner of Lecar window. The textPane is used for displaying all the data received from another PC and displaying the result after the calculation on the received data. Users can also review the history of the intersection control as in Figure 4. The "Method" pane is underneath "displayMovement" pane. It is a listPane. It will display the improvement methods and highlight the one being used. Users can change the method by moving the cursor to the method which is needed and clicking the left mouse button. The new method will be highlighted except for "changeThreshold" which will ask users to enter a new threshold for the number of cars in a queue. If "Manual" pane is highlighted, the calculation result

will be sent to another PC only when the user clicks the right mouse button at 'volume' or 'noStopped' in "method" pane, otherwise, the result will not be sent (TRRL, 1981), (Lin and Cook 1986).

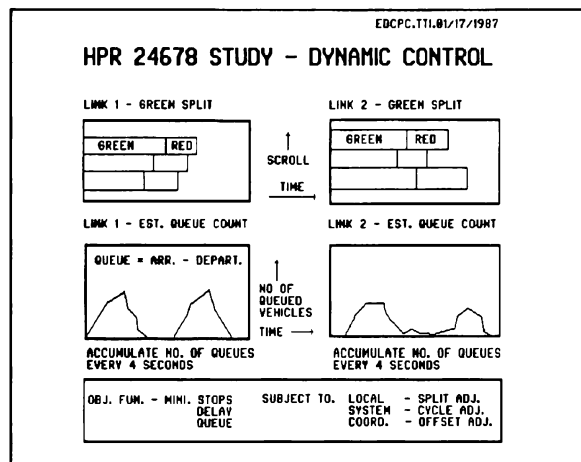


Figure 4: Historical Control Record.

The "Continuous" pane contains only a word 'continuous'. If this pane is highlighted and the word 'doNothing' is not highlighted, the result of the calculation will be sent to another PC at the end of each interval. The "Statushead" is a textPane located at the bottom right corner of Lecar window. The pane is used for displaying the status of the smalltalk program, for example, sending or receiving data to or from another PC or displaying what method is used for calculation. Finally, the "DoNothing" pane contains only a word 'doNothing'. If this pane is highlighted, the result will not be sent to the simulated PC for the continuous operations.

## 6. CONCLUSIONS AND RECOMMENDATIONS

This paper describes the development of An Intersection Signal Environment To Simulate Traffic Engineer Knowledge-Based Control through the dynamic graphics display and the smalltalk control environment. The system applies Artificial Intelligence Techniques and Expert Systems Designs to assist in the Selection of Different Computerized Signal Plans for Congested System Operations. It was intended for examining the different solution methodologies, such as the applications of advanced

signal control strategies and for developing efficient and flexible computerized traffic signal system designs and operations. The system can be used to evaluate the operational effects of using different object-oriented signal control strategies. Through the uses of different selection criteria, such as minimum standing queues, priority vehicle treatments, emergency pre-emptions, equal-saturation treatments, the system can display and simulate the outcomes, as illustrated by the variable phase sequences, flexible green time adjustments, etc., on the performance of traffic signal controls (Public Roads, 1979-1980).

The development of a macroscopic, graphics-based, interactive, signalized intersection simulation environment was made through the synchronized operations of two interconnected microcomputers serving as the "Simulated Real-world Intersection Controller" and "Supervisor Computer." To further improve arterial street and network signal operations under either the under-saturated or over-saturated urban operating conditions, the system can be used for selecting the optimal coordinated system background cycle lengths. At present, the system is equipped with heuristic methods through the AI/ES design techniques to accommodate variable traffic demands and different signal operation requirements during different time periods. Further expansion of the system will be made to investigate the operational trade-offs to execute strategies, and evaluate performance of different on-line timing plan switching methods to improve arterial street and network signal operations.

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Dr. Chang is a Registered Professional Engineer and Certified Civil Engineer in Texas and in Taiwan, Republic of China. He is also a member of the Institute of Transportation Engineers, Transportation Research Board, Operations Research Society of America, American Society of Civil Engineers, Association of American-Chinese Professionals, American Association for Artificial Intelligence, LEVEL5 Expert System/PRL Users Group, and North American Chinese Transportation Professionals.

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