*Abridgment*

# Signal Complaint Aid for Dispatchers (SCAD): An Expert System

KENNETH A. SHARP AND PETER S. PARSONSON

**A predictive, knowledge-based expert system to increase the efficiency of responding to traffic-signal malfunctions is outlined. Signal Complaint Aid for Dispatchers (SCAD) does not modify published research into a problem-solving routine. Instead, SCAD is the result of programming the signal engineer's decision-making process, in which the engineer first compares a traffic signal complaint with his or her knowledge and experience in the operation and maintenance of that traffic signal and then arrives at a plan of action. SCAD is designed to provide an engineer's in-depth knowledge of traffic signal theory and practice to a dispatcher who does not have the engineer's expertise in handling complaints. Expert systems are designed to solve complex problems that are poorly defined and not well understood. SCAD exhibits several of the advantages of an expert system. The program substitutes for the expert when it is impractical for the expert to be present. It provides expertise to lower-level personnel, such as a dispatcher with a high school education and a rudimentary knowledge of the roadway system. It is capable of learning from its mistakes by comparing its filed predictions with trouble call/response reports from the maintenance agency. SCAD documents the problem-solving knowledge that is being lost because signal engineers are leaving the public sector to avoid the increasing liability associated with their duties.**

The potential for personal injury and liability caused by traffic signal malfunction has caused many jurisdictions to establish formalized reactions for handling complaints from the public (trouble calls). Strategies that have been implemented to increase efficiency in handling trouble calls include a well-publicized telephone line dedicated to trouble calls, maintenance scheduling, inspection scheduling, computerized filing and reporting systems for traffic signal operations and maintenance, and the creation of specialized crews to respond to trouble calls. An expert system has been designed to make use of these strategies.

Accuracy is required in responding to a trouble call. The initial telephoned trouble call is often garbled, inaccurate, or incomplete by the time it is relayed to the response crew. Precious time is lost by notifying the wrong agency, dispatching the crew to the wrong intersection, or not taking the right equipment.

An expert system is designed to solve problems in the same manner in which an expert deals with them. The expert in the domain of trouble calls is the traffic signal engineer who is directly responsible for the timing and operation of the signals within the jurisdiction. The signal engineer has specialized knowledge of equipment and timings, traffic patterns, and maintenance history. Through telephone contact with and skillful interrogation of the person with the complaint, the signal engineer can often predict the cause of the field problem and instruct the response crew on what equipment to take, what to look for, what procedures to follow, and what procedures to avoid.

K. A. Sharp, Parsons, Brinckerhoff/Tudor Engineering, Atlanta, Ga. 30301. P. S. Parsonson, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Ga. 30332.

Signal Complaint Aid for Dispatchers (SCAD) is an expert system that has been developed to assist a dispatcher who receives a trouble call on a telephone. SCAD guides the dispatcher in asking questions of the caller, in contacting the right personnel to act on the matter, and in giving those personnel the information that they need. This abridgment summarizes the major points of SCAD. Copies of the unabridged paper are available from author K. A. Sharp.

## KNOWLEDGE BASE

A knowledge base is the portion of the expert system that contains the data describing the problem domain (*1*). In the case of trouble call/response the knowledge base includes specific information for each intersection. A data base of seven cross-referenced files was created to represent different aspects of the knowledge in the problem domain: the operational characteristics, the appropriate jurisdiction and the agencies involved, the recent history of incidents, the signalized locations with duplicate names, and specialized knowledge of the type of equipment, the phasing, and the timing. This information must be input to the knowledge base by the signal engineer. The expert system is designed to "think" like the signal engineer and must have the benefit of his specialized knowledge.

The data base used to develop and test the SCAD expert system consisted of 50 signalized intersections located within four jurisdictions known to author K. A. Sharp from his field experience in Richmond County, Georgia. The intersections were chosen to encompass the possible combinations of operational characteristics. The data base is designed to handle over 1,000 signalized intersections located within multiple jurisdictions. The maximum number of intersections that SCAD can handle is dependent on the data base software and available memory. MicroPro International Corporation's DataStar™ software was used to create the data base because this software produces an ASCII file that can easily be manipulated with BASIC. Ten BASIC programs were written to perform all data manipulations on the knowledge base files, to handle string processing, and to transfer data both ways between the knowledge base and the inference engine, which is described next.

## INFERENCE ENGINE

The inference engine contains the general problem-solving knowledge that is used to arrive at a solution (1). An inference engine consists of two parts: the production rules (IF . . . THEN . . . ELSE statements that use symbolic logic to represent strategies) and a shell program that supports the rules. Production rules are appropriate when the domain knowledge results from empirical associations developed through years of experience with solving problems in a particular area (1). Insight 2+™ version 1.3 by Level Five Research, Inc., was used to create the inference engine.

The SCAD inference engine is based in part on interviews with experts in the domain of trouble call/response (Howell Lancaster, Georgia Department of Transportation; Peter Parsonson, Georgia Institute of Technology; Marvin Rickard, Gwinnett County Traffic Engineering Department; David Amerson, Richmond County Traffic Engineering Department). During these interviews, situations were presented to each expert, and the method by which the expert arrived at a solution was noted and dissected in detail. The resulting rule-of-thumb decisions (heuristics) are put into the form of production rules and run with sample problems to compare the expertise gained by the computer program with the expert's real-world solutions.

For purposes of discussion, SCAD can be broken into three sections: contact-interrogation session, complaint-cause analysis, and notification procedure.

### Contact-Interrogation Session

The expert system is started at the moment of contact between the dispatcher and the contact. The computer's clock is accessed to set the time and date. The first item of input data needed by the expert system is the trouble call complaint. The request for information is presented to the dispatcher in the form of a multiple-choice question (menu) concerning typical signal complaints. The response to the question is then checked for overlap with another complaint on the list. For example, "conflicting indications" can be a symptom of a "twisted signal head." Clarification is made by questioning the contact.

After the complaint has been chosen, the expert system requests and verifies the location of the complaint. Then the contact is asked a series of questions about the complaint. These questions, which are based on the complaint type, reduce ambiguity in the description of the problem. They are presented to the dispatcher in the form of menu choices, true-false questions, and prompts for keyboard entry. Queries are refined with help screens that tell the dispatcher exactly what is desired in the way of a response. Some responses cue additional questions. When all questions have been asked, the dispatcher is told to hang up the telephone, and the contact-interrogation session ends.

The contact-interrogation session was designed to minimize execution time. The interrogation occurs in real time (i.e., while the contact is still on the telephone). The number of questions asked is also minimized. SCAD not only decides which questions to ask but also decides which questions not to ask on the basis of the complaint and on the answers to previous questions. Menus are used for data input whenever feasible to minimize the number of key strokes. On an IBM PC/AT or similar computer, the most complex interrogation routine lasts about a minute.

Execution time is the nemesis of an expert system. The control mechanism of the inference engine uses forward-chaining logic and pattern matching to search a tree in pursuit of its goal. Additional rules therefore increase the search time exponentially because alternate rules are being applied to the same situation. (With algorithms, on the other hand, the addition of rules changes the execution time only linearly or logarithmically.) Because of this exponential factor, many expert systems look good in prototype form but prove to be time consuming and unwieldy in the more complex production form (2).

Because of this exponential factor, SCAD is written in a modular arrangement to facilitate expansion of the variety of complaints (18 typical complaints are programmed currently) without jeopardizing the total execution time. Thus the execution time is dependent primarily on the time needed to search a file for the proper record. The greater the number of intersections, the longer the total execution time. External data access is kept to a minimum during the contact-interrogation session to ensure a short interaction time between the dispatcher and the contact.

### Complaint-Cause Analysis

After the dispatcher is told to hang up the telephone, the expert system uses a BASIC program to find the operational characteristics record for the location. SCAD compares this information with the complaint and other relevant information gathered in the contact-interrogation session.

The analysis is done in two steps. In the first step, the complaint and the gross operational characteristics are used to establish which general areas of signal operation (control, coordination, actuation, display, and/or timings) may be causing the complaint. Each general area is assigned a certainty factor ranging from 0 to 100. A certainty factor is a number that measures the analyst's confidence that a statement is valid (1). The sum of the certainty factors equals 100.

In the second step of the complaint-cause analysis, each general area of operation is examined and subdivided into specific operational characteristics: such as "solid-state controller" and "signal-conflict monitor" in the control area. On the basis of these specific characteristics, predictions are made of possible equipment malfunctions and the actions that will be taken to solve the complaint. Each solution has an overall certainty factor that is computed by multiplying the certainty factor of the general area times the certainty factor of that solution.

The expert system pursues all possible paths that yield solutions to the complaint. It checks for combinations of complaint and operational characteristics that are either impossible or else not indicative of a malfunction. For example, a flashing beacon that is reported to be on flash would not appear to be a malfunction. In such a case, a crew would be dispatched, but SCAD would form the prediction "Solution IS Do nothing—Location operating normally" and assign to it a high certainty factor.

## Notification Procedure

After predictions of the solution for the complaint have been made, SCAD enters the final phase of processing: the notification procedure. In this procedure, a printout is produced that lists the location and the description of the complaint (using data from the contact-interrogation session), the urgency of the response, the agencies to notify, the equipment to take on the call, the special instructions for each agency that will be dealing with the inspection or the complaint, and the actions that would require the trouble call crew to contact the signal engineer call (on the basis of the complaint-cause analysis). This printout contains information that will produce a quicker, more thorough response. SCAD's final action is to log the trouble call into the knowledge base's signal-incident history file, fixing the time at which the agency was notified of the complaint.

## SYSTEM REQUIREMENTS

To field test SCAD properly, an interested agency must be found. SCAD requires a dedicated telephone line, an IBM PC/AT-compatible with hard disk and internal clock, and existing computerized files of signal equipment inventories and signal incident histories. The files have to be stored in a form accessible by Insight 2+ or BASIC.

SCAD's memory requirements are extensive. Over 700 kilobytes of storage (700K) are needed. The SCAD inference engine (which presently consists of 415 production rules) requires 132K, and the Insight 2+ software that supports it needs 490K. The DataStar software occupies 72K, and the DataStar data files, input forms, and index files (the knowledge base) total 36K for the 50-intersection sample database. The BASIC programs that interface SCAD with the data base total 25K.

In this breakdown, memory required for storing the intersection data is only 5 percent of the total memory requirement. The final version of SCAD and a 1,000-intersection data base will require 1,500K (1.5 megabytes) of storage. A "fast" computer (based on 80286 or 80386 chip technology) will be a necessity for the final version.

## NEED FOR FURTHER DEVELOPMENT

As is often the case with expert systems, the developmental software is not the appropriate software for the production version. The software currently used is inadequate, particularly in the area of file manipulation. In addition, the software used to develop SCAD was acquired for educational purposes and not production purposes—distribution of SCAD in its present form may infringe on copyright laws. For these reasons, software for the production version (both the expert system and the data base) would have to be purchased, and SCAD would have to be rewritten.

The design of expert systems is an infant programming field. Adequate software does not yet exist, and new systems are being marketed almost weekly. The production software should have these characteristics: an affordable price, a compiler with run-time debugging features and variable name tables (extremely important because the expert system uses pattern matching, and names must be exact), certainty factors, extensive use of symbolic logic, complete and direct access (random access using index files) to a variety of commercial data base software, support for numeric calculations and string processing within the rule structure, good documentation, and for final distribution purposes, affordable run-time versions.

The data base software should be affordable, support cross-referenced and indexed files, and allow random access by the expert system. It would be preferable for the software to support an existing traffic operations data base. Before the SCAD expert system was written, a search was made for a commercial traffic signal incident data base and reporting system that was extensively used in the traffic engineering community. The intent of the search was to match the expert system to a standard traffic data base. The researchers found that there is no standard design for an incident file. A jurisdiction in need of such a system usually develops its own files, reports, and programs (Ken G. Courage, unpublished data). A data base was created for development of SCAD, but an existing data base would be preferred.

## REFERENCES

1. D. A. Waterman. *A Guide to Expert Systems.* Addison-Wesley Publishing Company, Reading, Mass., 1986.
2. H. E. Firdman. How Not to Build an Expert System Shell. *Computer World,* Vol. 21, No. 7, 1987, pp. 57–61.

*Publication of this paper sponsored by Committee on Traffic Control Devices.*