Some Design Considerations of Digital Computer Control Systems Applied to Freeway Traffic Operations

J. H. BUHR, D. R. DREW, J. N. GAY, and R. H. WHITSON,
Texas Transportation Institute, Texas A&M University

ABRIDGMENT

• BASICALLY, the objective of a freeway traffic control system is the optimization of freeway operation through the regulation of demand by controls exercised on the freeway entrance ramps. Because of the dynamic nature of vehicular traffic systems, the benefits of optimal utilization of freeway facility can best be provided by a real-time on-line control system.

This report concerns the design of a centralized digital computer control system for the surveillance and control of freeway traffic. It is primarily concerned with the analysis, definition, and development of system component requirements commensurate with the general nature of the control system specification.

The Basic Building Blocks

A freeway control system consists not only of the digital computer or central processing unit, but alsoof a variety of hardware devices. The equipment that constitutes an on-line control system can be divided into several classes, each consisting of various devices.

Data Processing Input/Output Units—The readers and printers serve as communication devices between the operator and the computer. The preferred freeway control system that is to serve almost exclusively as an operational (as opposed to research) device would have only a card reader and a typewriter as data processing input/output units.

Files—Control systems must store large amounts of information that can be rapidly retrieved for use in the control of the process. Such information is stored magnetically on tapes, drums, or disks. Of these, magnetic disks are the preferred files in the freeway control system.

Control Units—The control unit of the system is the central digital computer. It performs the calculations and logic and data manipulation and controls all the other parts of the system. At present, a single central computer will adequately serve the needs of control of all freeway control systems to be installed in the immediate future.

Communication Links—The transmission of data between the field sensors and the central computer forms a very important and highly specialized aspect of the control system. Its cost forms a substantial part of the total cost of a control system.

Process Control Input/Output Units—In order to control any process, the system must determine the status and environment of the process through its input units and then physically affect the process through its output units. In present freeway control systems, the input units are mostly loop detectors, and the output units are traffic signals placed on the entrance ramps.

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Some Control Considerations

The programming requirements of the control system can be thought of as consisting of four interacting subsystems: supervisory, control, data-acquisition, and analysis programs. These are discussed to acknowledge their existence and outline the purpose of each.

Supervisory Programs—In control systems it is often necessary to perform many functions simultaneously. There are communications to be handled, control parameters to be generated, and data to be recorded and displayed. All of this activity must continuously be scheduled and controlled by the computer as it is occurring. Priority decisions must be made moment by moment to decide what the computer will attend to next. This is the function of the supervisory program. It schedules the various parts of the control program and, when time and availability of storage permit, allows the compilation and execution of analysis programs not directly related to the control of the process. The supervisory program will also interrupt the execution of a certain task in order to service a higher priority job and, after servicing all higher priority interrupts, resume the execution of the original program.

Control Programs—The control programs consist essentially of the decision rules needed to improve the situation and the statements set up to change the status of the control devices designed to have the desired effect on the process.

Data Acquisition Programs—In order to achieve responsive control of a process it is necessary to continually measure certain parameters that describe the operation of the process. This is the duty of the data acquisition program. As such, it is a subsystem of the control program or the feedback required for the optimal control of a process. It also serves to evaluate and display the state of the operation for the benefit of the operating agency and can provide a permanent record of operation. The data acquisition subsystem further serves to detect equipment failures.

Response Time—Many of the considerations in the design of a process-control system are in some way connected with the response time of the system. Ideally, a short response time to all events is required. However, decreasing response times are directly associated with increasing costs. If a faster response time is desired, not only a faster computer, but also a larger computer and more rapidly accessible files may be required. In addition, faster response times may require additional transmission lines under certain circumstances.

Reliability and Standby Systems—The control system consists largely of a complex of sophisticated electronic equipment and as such is subject to periodic breakdown. Suitable arrangements must be made for this event by designing the system to modify its mode of operation when one of its components fail or, when necessary, to abandon a certain ramp to a simplified local controller which may provide for fixed-time control or simply a flashing amber sequence.

Design Considerations

Starting with a knowledge of the requirements, the objective of the design process is to find that configuration of functional elements which, translated into physical terms, meets the requirements as economically and efficiently as possible. Many factors enter into this choice of the proper configuration. The identification of the principal functions, the determination of their proper sequence, and the relative merits of centralization vs decentralization of control, for example, are but a few.

The design of a process control system is generally more complex than that of a conventional data processing installation. The hardware is more complex and many functions take place concurrently. The input to the system is not constant, orderly, and precisely predictable. The load on the system varies with time and occasionally reaches such peaks that processing is delayed. The penalties for errors in the design are also greater. If the load on a control system exceeds its capacity it may lose control of the process. In the unabridged paper, a step-by-step design procedure is outlined and each of the design requirements is discussed.

Implementation

The design and installation of a control system for purely operational purposes does not require lengthy data collection procedures by a large staff to establish a complete description of the operating characteristics of the freeway. With a knowledge of the requirements and procedures, a control system can be installed and made operational in considerably less than one year.