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INTERNATIONAL SYMPOSIUM ON COMPUTER CONTROL OF NATURAL RESOURCES AND PUBLIC SERVICES

by I. Estermann

23 October 1967

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UNITED STATES OF AMERICA

INTERNATIONAL SYMPOSIUM ON COMPUTER CONTROL OF NATURAL RESOURCES AND PUBLIC SERVICES

I. INTRODUCTION

Sponsored by the Applications Committee of the International Federation for Automatic Control (IFAC), the Symposium convened at the Technion, Israel Institute of Technology, in Haifa, 11-13 September 1967. Although substantial participation from abroad, including countries of the Eastern Block had been expected, all the scheduled speakers from the Eastern Block and India and a few from other countries failed to appear. As a result, the original program of 40 papers was reduced to 29, with the beneficial effect that all but one of the parallel sessions were eliminated. The session on Theoretical Aspects of Automatic Control, to which speakers from the Eastern Block were to have been the main contributors, was cancelled altogether. Whether for reasons connected with the Israel-Arab war and its aftermath, or for other reasons, the participation of scientists and engineers from abroad was far below expectation and amounted only to about thirty, but participants from Israel made up for this deficiency and brought the attendance at some sessions over the 200 mark.

The technical program dealt with the following general topics: water supply, oil refineries, power stations, vehicular traffic, and telephone systems. Most papers were descriptive in nature and provided details on systems in operation or in the planning stage. Of wider interest were several review papers containing discussions of general principles and the philosophy of automatic control.

II. REVIEW PAPERS

The keynote paper with the title, "Solving the Problem of Physical and Social Resources," was given by J. Aseltine (TRW Systems, Redondo Beach, Calif.). The author discussed the general nature of the problems caused by the rapid expansion of the social organism and possible solutions. The population explosion is causing a very fast increase in demands on the community's physical and social resources, which must ultimately lead to a crisis unless appropriate measures to relieve the stresses are taken in time. Examples of physical resources which are already overtaxed are environment (congestion of cities, pollution of air and water, accumulation of wastes), mobility (traffic), and services (power, water communication); similar problems exist with respect to such social resources as public health, safety, and education. To illustrate the situation, Aseltine pointed out that in general we try to solve these problems by the incremental method, i.e., by providing additional channels or units, such as widening a highway, installing another generator at a power plant, building a new school or hospital, etc. In his opinion, this approach is bound to fail because it only postpones the arrival of the crisis stage by shorter and shorter periods. (The writer was reminded of a course in economics which he took almost 50 years ago at the University of Berlin, where the professor explained the Law of Diminishing Returns in connection with agricultural economics.) The proper way to deal with these problems is the Systems Engineering Approach, which the speaker defined as the use of a "combination of disciplines not normally associated with the problem at hand." This approach, however, requires a great deal more attention than the incremental treatment, and -- to quote the author again -- is generally not used until the crisis stage is reached. To illustrate his rather pessimistic outlook, he proposed a "Crisis Law" which he formulated as follows: "Problems of improving physical and social resources are solved incrementally until the crisis stage is reached; after that, only the systems approach can provide a solution, if one exists." As examples of problems approaching crisis stage he mentioned hospital and health services, with transport, air and water pollution close to it, and our large cities not far from crisis stage. Hospitals, for example, should be so organized that doctors and nurses would be relieved from collateral duties, such as keeping of records, which could be transferred to a computer, routine laboratory work, which should be automatized, etc. The cardinal problem is to determine priorities. In this context, the constraints are not only technical and economic, but also political -- politics being the "science of the possible."

Another review paper was presented by S. Shapiro (IBM Advanced Development Division, USA). His subject was "Computer Simulation of Control Systems," and he discussed primarily the relative advantages of analog and digital computers for various classes of problems. The analog computer is easily adaptable to continuous processes while the digital computer responds better to discrete processes. Other factors to be considered are cost, size, speed, memory, precision, space requirements, maintenance, etc. A drawback of the digital computer for simulation operations is the necessity in many cases for the development engineer to use a "middleman" -- the computer operator -- and receives his results generally in the form of large stacks of print-outs which are worthless if an error has crept in at an early stage. On the other hand, he would normally operate the analog computer himself and thus be able to "debug" his system quicker and more effectively. With the advent of time-sharing, on-line consoles and new methods of data presentation, the digital computer is gaining ground and may ultimately replace the analog computer in many applications. Shapiro was not very enthusiastic about the use of hybrid (i.e., combination of digital and analog) computers, which at first sight appeared very attractive but which, in his opinion, emphasize the shortcomings of both types without equally enhancing their advantages. His advice was: Use a hybrid computer only if you cannot solve your problem on a digital or an analog computer.

The third review paper to be mentioned here was the closing address of the Symposium, entitled, "Control and Prediction," given by J.F. Coales (Cambridge Univ.). He began by defining "Prediction" as an open-ended, and therefore essentially stable operation, and "Control" as a feed-back operation which can lead to a runaway situation because of its inherent instability. Another problem of "Control" of large, complex systems are the long relaxation times which are sometimes involved. As an example, Coales used the production of grain in a national economy. One of the variables is available manpower. If the demand for grain increases, a control system would assign more manpower to its production; to feed this manpower, the system would release more grain and in the end possibly use up the reserves for seed grain so that there would be no production the next year. Or, if a power company should discover by means of a control system that its generating capacity was insufficient, it could not correct the situation in less than a few years and would in the meantime be unable to meet the public demand.

When the cost factor is also considered, it is evident that automatic control can be used only to manage short-term fluctuation; for long-term planning, accurate prediction of load patterns and demand is essential. Linear programming, and in some cases non-linear programming, techniques can then be used to decide the most efficient way of meeting the predicted demand, taking into account all the relevant variables. At this stage, there is no place for over-all feedback control. A similar situation exists in many businesses and factories which are also far too complex to be candidates for over-all feedback control. Only individual manufacturing processes are usually simple enough to permit the useful application of feedback control. A control system may be used to keep certain manufacturing parameters, e.g., pressure temperature, flow rates, etc., within prescribed limits, or to change these parameters to compensate for unpredictable (small) changes in raw materials or external conditions under which the plant operates. If the physics and chemistry of the manufacturing processes were fully understood and if the relevant properties of the raw materials, etc., could be measured continuously and instantaneously, a computer could be assigned to calculate the necessary changes in operating parameters and no feedback control would be required. In the days before automation, this function was the job of the skilled foreman who had learned by long experience exactly what to do in such cases.

Over-all feedback control is usually uneconomic because in most plants many operations are required to convert raw materials to finished products, and by the time the sensor detects a sufficiently large deviation from specifications of the properties of the products, a great deal of unsatisfactory material is already in the pipeline which cannot be salvaged by corrective measures. Coales explained this process by a detailed description of the operations of a steel mill with particular emphasis on the rolling process, and developed the equations needed for computer control of the parameters of the various stages of production of uniform sheets. He pointed out that for the initial setting of the mill, prediction based on a working model of the process is necessary and that automatic control is used for correction of small perturbations.

If one could predict accurately for several years ahead which goods and services the public will require and what a country can afford in the light of world conditions, one could predict the quantities of basic commodities required to meet this demand. Programming techniques could then be used to decide how national resources should be allocated for optimization of the national economy. If dynamic models for the various plants can be constructed, computers can not only help on control problems, but can also aid in the design of these plants. One thing, however, that the computer cannot do is to provide new ideas, and it is therefore essential that the designer and the computer work together and supplement one another.

III. TECHNICAL PAPERS

We shall now review some of the papers dealing with specific applications of computer control.

1.) Power Stations

H. Unseld (Technical Univ., Stuttgart, Germany) described the automatic operation of a combined steam heating and power plant of medium size (3.8 MW) installed at the Technical University, Stuttgart. The plant consists of two steam generators, two steam turbines with attached generators, and a heating system with circulating pumps and heat accumulators. The control system employs electronic switching for the start-up and shut-down phaes, while the normal plant operation is monitored by a process computer of conventional design with on-line closed-loop control. The system is of modular construction, utilizing four types of units only, viz., the sequence unit, the output unit, the time unit, and the AND unit, each of which utilizes printed circuits. Starting procedures are activated by a single push-button and require a sequence of eight steps. About 30 minutes are needed for a cold start; shut-down, also activated by a single push-button, requires only five steps. Over a period of less than two years, the system was started and shut down 292 times with no failures on the control side and only minor troubles on some auxiliary components. Only two operators are needed for each shift.

Y. Wallach (Technion, Haifa) submitted a paper on a digital computer program for the calculation of short-circuit currents in multiphase electrical distribution systems. He also developed the differential equations for the melting of a fuse. For computation, the conjugate-gradient method developed by Hestenes (Proc. Symposium Appl. Math., Vol. VI, Mc-Graw-Hill, New York, 1956) was used.

2.) Vehicular Traffic

H.N. Yagoda (Polytechnic Institute of Brooklyn) discussed various philosophies for control of traffic on a one-way arterial street and their objectives, such as smooth flow, minimum total delay, maximum capacity, etc. Choosing the smooth-flow philosophy as a basis for the analysis, he examined three control systems for a section of 7th Avenue in New York between 23rd and 57th Streets. The first system is a uniform signal progression at 50 ft/sec with a 40-sec cycle and a one-to-one cycle split which is similar to the system currently in use. The second system corresponds to an optimum pre-programmed progression for the same cycle length and a 50 ft/sec design travel speed but with optimum cycle split. The progression speed is pre-determined for different traffic demands for several periods of the day. The third system is a feedback control system responding immediately to fluctuations in traffic demand. The last two systems are superior to the first; system number two is for arterial streets with a heavy demand varying in essentially the same predictable way every day, and the last one is for streets which exhibit heavy, unforeseeable traffic fluctuations.

H.K. Salmivaaro (Traffic Engineering Dept., Helsinki, Finland) described the traffic-control system planned for Helsinki. After defining the objectives of the system in much the same way as the previous speaker, he expanded the problem from that of a single arterial highway to that of a complete network, introducing a digital computer to control a group of traffic signals from a central location. The advantages of this system are its ability to acquire traffic information from hundreds of vehicle detectors on a second-to-second basis, to assimilate this input, and to convert it to control impulses for the operation of the traffic signals in accordance with actual traffic requirements. It can also be used to store and analyze traffic data for further improvement of the system. He also provided characteristic data about the metropolitan area of Helsinki. It covers 70 square miles, has a population of 700,000 and 72,000 cars in operation, and consists of a central business district at the tip of a peninsula and residential suburbs on three sides. It is planned to construct a ring road 1.2 miles in diameter surrounding the central district and to terminate a number of radial freeways at this road. The inner section, containing many old buildings and historical landmarks, is to be preserved as much as possible, and its traffic problems will be solved mainly by the assignment of one-way streets and ordinary traffic signals. No through traffic through the central area is contemplated.

The control system selected for the outer area is a VSR 1600 model manufactured by the German firm, Siemens & Halske. Its basic components are a special-purpose computer, a central processor, and a signal program processor. The last, which is of relatively simple design and therefore of very high operating reliability, handles the extensive routine problems of traffic control according to predetermined programs, but obtains its program selection from the central processor. If the latter fails, the system will continue to function according to the last program inserted but without optimization. The individual signal programs (up to 16) are established by the traffic engineer for each intersection, and the computer selects the appropriate program for each intersection on the basis of actual traffic conditions communicated to it by the vehicle detectors. The established programs can be modified within certain limits by the central processor to match existing traffic conditions. The central computer can accommodate up to 160 intersections; if more need to be controlled, the network will be divided into districts equipped with individual computers. The first stage of the installation will contain 50 controlled intersections at a total cost of $3 million. Ten per cent of this sum will be the cost of the computer. The system will also provide for diversionary signals to re-route traffic away from overloaded sections.

G.A. Ferrate (Technical University, Barcelona, Spain) discussed a control system for the central part of Barcelona, consisting of a central processor and a number of sub-area controllers which can function independently if the central controller fails. Each sub-area has its own computer controlling 15 to 32 intersections, all operating on the same cycle at any one time. Each control program is composed of a set of coordinated "green waves." Transitions from one program to another will be gradual in order to avoid transients which may cause traffic pile-ups.

A. Adoram (Signalor Ltd., Tel Aviv, Israel) described a special-purpose computer developed by his company for a regional network of 200 traffic signals in Tel Aviv. This computer serves as master element for the control of a number of traffic areas, defined as regions in which traffic characteristics are sufficiently uniform to allow control with the same cycle length. The computer gives instructions to a master controller which in turn activates local controllers for the operation of individual traffic lights in any one area. The computer determines the optimum cycle length for each area according to existing traffic conditions and the proper division of the cycle into green and red periods for each intersection. It also provides coordination between adjoining areas and activates diversion signals when traffic conditions in a particular area reach saturation. The computer input is composed of fixed data (reflecting traffic capabilities of each street), which are set in advance by the traffic engineer, and variable data reflecting traffic volume and speed, which are fed in by traffic counters on a continuing basis. It is also capable of storing data for further analysis and improvement.

3. Telephone Exchanges

The automatic telephone exchange is probably the best-known example of successful application of automation. Less well-known is the fact that the fantastic expansion of demand for telephone service in many countries has already put a severe strain on existing techniques which can no longer be satisfactorily relieved by the incremental method (cf., the review paper by Aseltine). The telephone industry is, therefore, one of the most active performers in the search for new methods employing the most recent advances in control techniques. Even in a relatively small and still 'developing' country such as Israel, the Telephone Administration of the Ministry of Posts is devoting a substantial effort to the investigation of new methods which may help to satisfy the enormous demand for new telephone service without overstraining the financial and manpower resources of the country.

J. Lavie (Ministry of Posts, Jerusalem, Israel) was the first speaker in this section of the program. He discussed the philosophy of his Department for the solution of the many problems which plague the local telephone network. To cite a few figures: There are at present 220,000 telephone lines installed and 330,000 individual telephones in operation. The difference between these two figures is due to the widespread use of party lines. The network is served by 80 automatic-switching centers arranged in ten areas. Direct dialling is in operation throughout the country. The total investment in telephone facilities to date is 5 million Israeli pounds (about $1,670,000) and is expected to reach 300 million pounds in 15 years. About 20% of the investment is allocated to equipment for inter-city traffic.

In order to make the most economical use of this investment while ensuring a high degree of reliability (Israeli specifications require 99% performance), it has been decided to install a Centralized Control and Supervision System (CCSS) for the whole telecommunications network. This system will provide: (1) Fault location with the aid of a central display, (2) Simultaneous traffic load measurements over the whole network, and (3) Constant contact with all engineering centers to facilitate the assignment of manpower for the correction of faults or emergency operations. Lavie expressed the opinion that large safety factors or redundancy of equipment are money spent in the wrong place; the system must be designed to perform properly and to eliminate possible bottlenecks before they appear. The CCSS is supposed to fulfill these requirements. It is already partly in operation and is being used for fault localization.

A. Atar (Teco Ltd., Bne Brak, Israel) talked about a control system for an electronic telephone exchange of the REX 18 type. Mr. Barnard of AEI, builders of the exchange, described the switching system. Its basic feature lies in the use of three-stage switching arrays which can be arranged in multiple units, allowing installation of from 2000 to 100,000 units in a single exchange. He explained the design principles by analyzing the function of the human operator in a manual exchange and relating it to the operation of the components of the automatic system. The main principle is the separation of control and switching operations and their assignment to different units.

G.B. Bradshaw (Signal Research and Development Establishment, Christchurch, Hants., UK) entered a paper on a Computer Controlled Digital Switching System for Pulse Code Modulation (PCM) Telephony. In his absence, the paper was read by M. Ward (GEC Telecommunications, Ltd., Coventry, UK). Ward said at the outset that he had a number of objections to the proposed system (which had been conceived as a military communications system and was, therefore, not comparable to commercial systems). The main criticisms were: (1) that no thought had been given to economic considerations; (2) that the system lacked flexibility and was, therefore, not sufficiently reliable for military purposes; and (3) that it operated with a very high noise level.

In a paper presented in his own name, Ward discussed general principles of Computer Control of Telephone Exchanges. Like Lavie before him, he pointed to the rapid expansion of demand for telephone service, which made the incremental increase of facilities no longer practical. Radically new techniques have to be introduced, but this approach creates other serious problems, mainly on the economic and operational sides. One cannot simply scrap existing equipment before the end of its normal life -- 30 to 40 years -- and must, therefore, demand that new equipment be compatible with the old. Transition to new types of equipment or components must proceed without interruption of service -- a very difficult requirement for the designer. New equipment must also be capable of transmitting facsimile, video, data and computer signals in addition to undistorted speech, and at the same time, its cost must be held within reasonable limits.

The speaker listed four design requirements that must be met in order to solve these problems: First, separation of signalling and transmission; second, separation of switching and control; third, standardization of hardware; and finally, flexibility. These requirements can be met by the introduction of computer control, because the different functions of the exchange are then activated by sequences of instructions from the stored program in the computer and do not depend on the configuration of the "hardware." This feature permits the manufacturer to produce standarized equipment and leave details of their functions to the "software," which can be modified as needed; if necessary, from a remote control point. Moreover, the computer can divorce the speech path from the control path circuit, and can operate with different types of switching equipment, e.g., reed relays, crossbars, pulse control modulation (PCM), or a mixture of various types. To be practical, the control system should be capable of handling additional service facilities which may be developed during its lifetime and of absorbing a considerable increase in the number of stations to be served. It should also provide sufficient redundancy to prevent complete system failure through a single fault. All these conditions must be met without an excessive cost penalty.

The solution proposed by the author is a multi-processor system which he described in detail. Only a few features shall be mentioned here. Each processor consists of a control unit, an arithmetic unit, and a register unit. The traffic load is shared by several processors, but each is capable of performing all exchange functions so that in the case of failure of one processor, only the capacity of the exchange will be reduced. Since any exchange is operating near capacity for only a limited time during a day, the computer would be available for other functions during light-load periods. The control system has been designed and a prototype has been completed.

To return to Israel's telephone problems, we shall review two more papers.

O.G. Waas (Albiswerk, Zurich, Switzerland) gave a report on "Electronic Control of the International Trunk Switching System ESK A 64 for Tel Aviv." This facility is now under design by Albiswerk and will connect Israel's national network with international centers in Europe and overseas. It will form the terminal equipment for an undersea cable now being laid between Israel and France. Since this cable represents a considerable investment, and since it will not carry through traffic beyond Israel so long as the present political situation persists, the terminal equipment must allow complete utilization of the capacity of the cable. At the same time, it must be compatible with the different switching systems used in various countries. In the present stage, the system is designed for semi-automatic operation, but it will ultimately permit fully automatic traffic.

Y. Baal-Shem (Technior, Haifa) spoke on the "Possibility of Using Pulse Code Modulation (PCM) within the Israel Telephone Network." In view of the rapidly increasing demand for telephone service in Israel, the use of multiplexing instead of additional cable installations is now being considered for local service. Multiplexing equipment in use requires special low-loss broad-band cables which are installed on many long lines but not on existing urban circuits. New multiplexing equipment based on PCM, which permits operation with a low-quality link, is now becoming available. This system requires speech digitalization, i.e., the breakdown of the continuous carrier modulation into a number of coded pulses for transmission purposes, and the reconstruction of the original wave form (or one near it) at the terminal point. Baal-Shem studied both the technical and economic factors involved in the introduction of PCM in Israel, and although his results are not quite conclusive, he finds that for distances of more than 15 km (10 miles) between the exchange and a group of subscribers, PCM would be cheaper than the installation of new cables. Under certain circumstances, the break-even point may be reached at even shorter distances.

In view of the philosophy expressed by Aseltine, which seemed to permeate the whole Symposium, an early consideration of digital techniques for voice communication seems to offer one way of postponing the "crisis stage" which our telecommunications systems are approaching.

IV. SUMMARY AND CONCLUSIONS

In recent years, it has become an accepted practice to schedule international conferences in rather out-of-the-way places, and very often the participants from the host country have little to contribute to the subjects under discussion. This conference certainly did not warrant this type of criticism. It was gratifying to see that even such a sophisticated subject as Computer Control of Automatic Systems has received serious attention in a small, developing country and that active participation was about evenly divided between hosts and guests. The discussions were lively and on a high level, the arrangements functioned smoothly, and practically all the participants had sufficient knowledge of English to eliminate the need for translation services. The subjects under discussion were timely and their rapid development was reflected in the formal presentations as well as in the informal discussions.

APPENDIX

A. PAPERS PRESENTED BUT NOT REVIEWED

1. R. Perret (France)
   Automatic Control and Scientific Research

2. A. Wiener (Israel)
   The Israel Water System

3. J.A. Aseltine and C. Stableford (USA)
   Application of the Techniques of Space Technology to Water Resources Control

4. R.E. Larson and W.G. Keckler (USA)
   Application of Dynamic Programming to the Control of Water Resources System

5. D. Karmeli, A. Shani and Y. Gadish (Israel)
   Dynamic Design of the Water System Using a Special Purpose Computer

6. O. Levin (Israel)
   Optimal Control of a Storage Reservoir during a Flood Season

7. E.J. Neugroschl (USA)
   Computer Control Aspects of an Activated Sludge Treatment Plant

8. N. Gartner and J. Ben-Uri (Israel)
   Digital System for Traffic Signal Control

9. A. Carmassi (France)
   Optimization of the Production Units of Sulpherine starting with Sulphuretted Hydrogen

10. E.C. Ogbuobiri and S. Linke (USA)
    A Unified Algorithm for Loadflow and Economic Dispatch in Electric Power Systems

11. W.K. Roots and I. Widenitz (USA)
    Temperature Control in Electrically Heated Homes in the US

12. E. Gottlieb (Israel)
    Rapid Numerical Evaluation of Laplace Transform and Transfer Function

13. J. King, T. O'Ca na inn and S.L. Stott (Ireland)
Design for a Learning Controller

14. T. Ogen (Israel)
A Fault-Detection Method for Telephone Switching Equipment

B. <u>PAPERS ON THE ORIGINAL PROGRAM BUT NOT PRESENTED</u>

1. E.E. Makovsky (USSR)
Dynamics of Irrigation Systems Regulation

2. H.H. Führer (Germany)
Automation in Road Traffic

3. Y.K. Jain (India)
Suboptimal Control of Electric Trains

4. L.A. Yardeni (USA)
Computer Aided Traffic Signal Control Systems

5. C.B. Speedy and D.A.J. Dyer (Australia)
Modelling of a Steam Generator for Computer Control

6. L. Bental (UK)
Train Description Control by On-Line General Purpose Computer

7. S. Mukherjee, S. Das Gupta and B. Majundar (India)
Relative Stability Boundaries of a Second Order System with Transport Lag

8. I. Popchev (Bulgaria)
Some Mathematical Models of Resource Control

9. A.Y. Lerner and I.M. Makarov (USSR)
Some Problems of Optimal Control of Resources

10. A. Straszak (Poland)
Suboptimal Control of Resources in Large Scale Systems

11. Yung Lung Ma (Taiwan)
Optimal Estimate for some Automatic Control Systems

12. V. Simon (Hungary)
Some Industrial Uses of the Binary Rate Multiplier

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Israel, natural resources, public services, water supply, oil refineries, power stations, vehicular traffic, telephone systems, computer, computer-aided design, control, processor						

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13. ABSTRACT

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