MERCEDES — AN INTERACTIVE PROCESS CONTROL PROGRAM PACKAGE FOR A PORTABLE COMPUTER LABORATORY

By

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Introduction

Nowadays production has been characterized all over the world by intensive emphasis laid on economic questions. In control engineering this demands optimal control systems, satisfying certain cost functions.

Several classical and up-to-date synthesis methods are known for designing optimal control systems. Effective and quick application of these methods, however, necessitates the use of digital computers. Neither configuration of hardware system, determined by the nature of the task, the available resources, the conception of the economic and the technological management, etc. is irrelevant for the succesful achievement. At the same time a computer system, whatever well constructed, cannot work efficiently without a software system developed up to requirements. The succesful solution of a control problem is only possible, if the hardware and software systems, worked out correctly, are simultaneously realized.

On the basis of these considerations, co-workers of the Research Group for Automation of the Institute for Research and Planning in Silicate Industry (IRPSI) and the Department of Automation of the Technical University, Budapest decided to work out a general-purpose process control program-package for a Portable Process Computer Laboratory (PPCL) established earlier by IRPSI for controlling various kinds of processes in the silicate industry.

The precedents of elaborating this program-package date back to some years. In 1975 co-workers of IRPSI and the Central Research Institute for Physics have developed and set up the above mentioned PPCL, consisting of a process control computer (TPA/i—similar to the PDP8) and a CAMAC system as a real-time periphery in order better to know and control technologies in the silicate industry. The PPCL developed in this way is

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suitable for on-line controlling various processes, through mobility and easy connection to the process.

In 1975, IRPSI committed the Department of Automation of the Technical University to make ready the process control model for the second furnace of the Hollow Glass Factory in Orosháza (Hungary). In lack of programs necessary to complete this model, the results of data processing had to be punched on tape to be evaluated later. A difficulty resulted both from the long measurement and identification cycles and from data punching, at the same time the model did not reflect the instantaneous furnace conditions.

To eliminate these problems the IRPSI offered a possibility to test an adaptive control algorithm—developed at the Department of Automation—on the PPCL and to try it out on the process – "in vivo". The results were good. The furnace pilot operation became smoother than under local control.

These two circumstances, that is, awkwardness of identification on a computer, not belonging to the Glass Factory and advantage of the on-line (real-time) algorithm induced the Automation Research Group of the IRPSI and the Department of Automation to agree on mutually developing a computer control program package for the existing PPCL. This program package was completed in 1978 under the name

MERCEDES

(Moving computER Control and procEss iDEntification System).

The program system MERCEDES is suitable for fulfilling various tasks on the site of technology. These are:

- data logging;
- primary evaluation of data (monitoring, graphical display, averaging, etc.);
- generation of a prescribed intervention signal;
- calculation of an adaptive controller algorithm;
- intervention (reference signal, test signal, DDC, etc.);
- identification;
- controller design.

The program-package of the structure seen in Fig. 1 meets these tasks with the use of up-to-date algorithms. The program system consists of two main

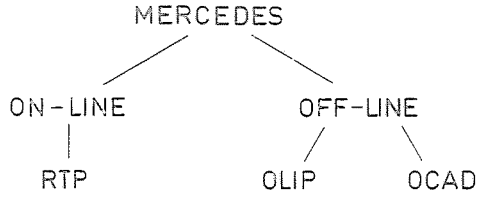

Fig. 1

parts: the on-line and the off-line program packages. Two further components of the off-line program package are: the OLIP and the OCAD program packages. These names arise from the following abbreviations:

RTP – Real-Time Program package
OLIP – Off-Line Identification Program package
OCAD – Off-line Computer-Aided Design program package.

RTP — Real-Time Process control program system

The RTP is intended to establish direct connection with the process and two-way signal flow (data logging and intervention), to process collected data and realization of the discrete control algorithm. The parts of RTP are:

SYS-IM – SYStem Initialization and Modification subsystem;
DALO – DAta LOgging subsystem;
NOLID – Nonlinear On-Line IDentification subsystem;
DDC – Direct Digital Control subsystem;
ST – Self-Tuning minimum variance control subsystem;
TEGE – TEst signal GEnerating subsystem;
INVE – INterVEntion subsystem;
DEVAL – Data EVALuation subsystem;
INT – INTerrupt subsystem.

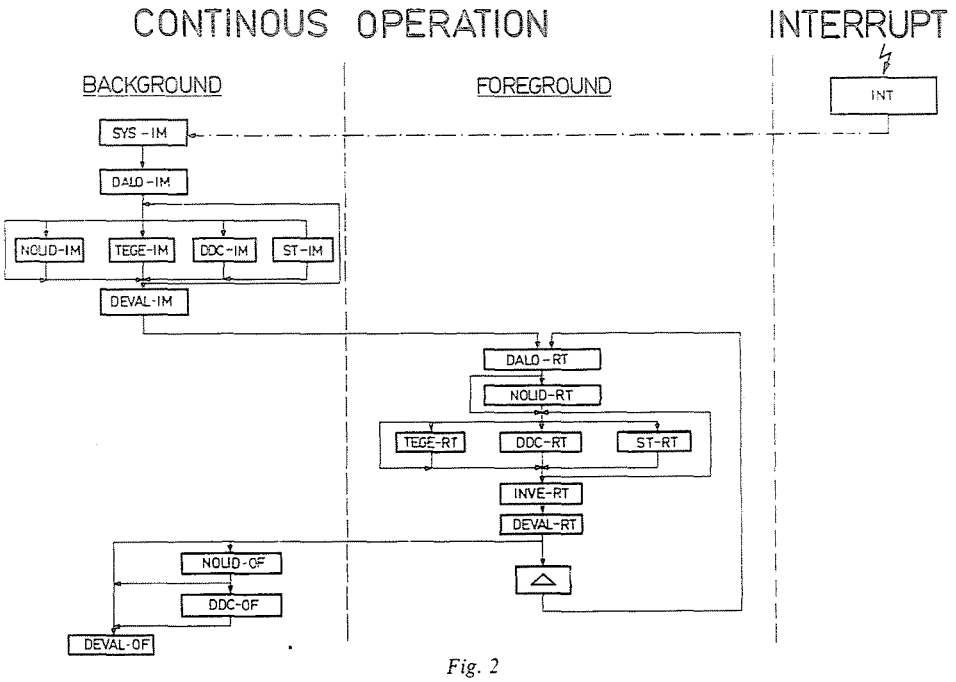

Fig. 2

The scheme of the RTP system is shown in Fig. 2. The meaning of the letters with hyphens beside the program names is:

IM – Initialization and Modification module
RT – Real-Time operation module
OF – OFf-line operation module.

From the scheme the system is seen to be organized so that the initialization and modification, moreover the off-line (OF) modules are in the background, the RT modules in the foreground zone. It is possible to choose interrupt mode of operation.

Initialization of the system is followed by the initialization of the particular functions. Then the RT modules operate by sampling intervals. After a preset interval the OF modules—whose execution depends on the operator's command—appear periodically. By way of interrupt it is possible to call a SNAP from the background at any time. Similarly through an interrupt the RTP system parameters can be modified. At that time after interrupt the control gets to the IM module.

The subsystems of RTP and their tasks are:

SYS-IM: a subsystem for reading in data necessary for system initializing and optionally for modifying subsequently.

DALO: a subsystem for data logging, in particular:

- data logging;
- credibility test (static and dynamic);
- conversion into physical magnitudes in knowledge of the given measurement process and the parameters of the measuring equipment;
- evaluation of the measurement error and noise filtering;
- data recording on COMMON, disc or punch tape.

The subsystem NOLID is suitable for real-time identification of static and dynamic, linear and non-linear, single and multi-input processes. The process may be also nonlinear and dynamic, but it must be linear in parameters. The utilized identification method is a two step method. Accordingly the subsystem NOLID consists of two modules.

Module NOLID-RT is expected to recursively update the correlation functions. Module NOLID-OF (belonging to the real-time program package, but evaluating off-line) fits a model to the correlation function computated by the module NOLID-RT on the principle of least-squares parameter estimation.

The subsystem NOLID is an appropriate tool of real-time interactive experimental evaluation, as the correlation functions are updated recursively at a rhythm imposed by the data collection, while the interactive—off-line—evaluation permits the quick choice of the appropriate model components, the order and the dead time. During interactive evaluation the real-time modules

are continuously working, so in a later phase a new, exacter evaluation is possible on the basis of correlation functions accumulated in several measurements.

The subsystem DDC consists of two modules. The module DDC-RT evaluates the intervention signal on the basis of the vectors of measured data and of reference signal, stored in COMMON field.

Module DDC-OF designs controllers of linear SISO (single input, single output) control systems for a given process and feedback model.

A control algorithm adapting its parameters to the changes of the system and the noise parameters is also part of the real-time program-package. Introduction of this Self-Tuning algorithm—developed by the school of the internationally renowned Professor Åström and first applied in Hungary by the Department of Automation, Technical University, Budapest—highly raised the level of services of the system.

The task of adaptive controller subsystem ST is to design a minimum variance controller. In order to reduce the running time, separate programs were made for controlling MISO and MIMO systems.

The module ST-MISO-RT performs real-time recursive updating for the adaptive control of linear, dynamic processes of single and multiple (max. three) inputs but a single output. So does the module ST-MIMO-RT for processes with several (maximum three) outputs.

The task of the subsystem TEGE is to set the appropriate working points and jumps, the changes according to a given schedule necessary for the qualitative acquaintance of the system and to generate the excitation indispensable for identification.

The subsystem INVE has to emit the intervention signals computed by the RT modules, to check static and dynamic restrictions before emitting the intervention signal and if needed, to modify the emitted signal.

The task of the subsystem DEVAL is the primary evaluation of measurements and intervention signals as well as data supply for the technology (printing the measured data and intervention signal, graphical display data, average and variance computation, observation of technological limits, logging, etc.).

The subsystem INT has a double task. On the one hand, it enables calling off-line evaluating, identifying and designing SNAP-s at any time, on the other hand, after interrupt it permits to modify system parameters by activizing initialization and modification (IM) modules.

Off-line program-system

The off-line program-system consists of program packages OLIP and OCAD.

OLIP evaluates the collected measurement data of RTP with the purpose of off-line modelling. Its main functions are: preparation of data, display, parameter estimation, model verification. The constructible model categories include the single and multiple input, linear and nonlinear, static and dynamic systems with linear parameters. These models proved to be satisfactory in case of many industrial problems.

OCAD has to design a controller based on the process model either known or determined by identification. The design procedures include the classical and modern synthesis methods of control engineering. Subsystems (FRECAD, ROCAD, INCAD, SIMCAD) determine the wanted control parameters by the methods of frequency, root-locus, by minimizing the integral criterion of least squares and by the simulation method. The block-oriented simulator SIMCAD allows to apply the analog computer technique on digital computer.

Experiences with software development

As introductorily mentioned, the program package MERCEDES was made for the PPCL of IRPSI. The languages for the on-line system was OPAL and for the off-line system FORTRAN.

Recently OPAL is the only high-level process control program language used in Hungary, therefore—in lack of a better basis of comparison—the advantages of OPAL are referred to the high-level process control program language INDAC, used earlier.

OPAL is a new language, consisting of instructions similar to those in BASIC. OPAL adopted many features of the earlier system INDAC, but with considerable additions, useful services.

In elaborating MERCEDES, the advantages of using the language OPAL were—among others—as follows:

- it contains new instructions, e.g. instruction bracketing, instruction for handling bits;
- it realizes a new COMMON sectioning;
- the field of common data in the usual sense means the storage area being in the memory all the time;
- the field of DATA is a storage area handled by DATA segments, with characteristic data may be read from the disc or may be stored on disc;
- it contains a new segment (FUNCTION);

- it is completed with new auxiliary programs, making debug easier, such as;
- fault seeking and tracing program: POLIP
- a program PRESTO for the correction and modification of the object program;
- it cuts the running time.

This is no complete list of all the advantages of the language OPAL over the system INDAC, only points out the features of importance in application.

Using language FORTRAN in the process control computer TPA/i, working in the OS/I system, the PPCL appeared to maximally help program development by providing a quick, flexible compilation and overlay at a rapid translation.

In elaborating the process control program package MERCEDES an additional advantage was the availability of floppy discs in the PPCL for storing source files, relocating files and ready programs.

General characteristics of the program package MERCEDES

The process-control program-package masters its tasks by means of up-to-date algorithms known from the international technical literature and proved in practice.

The programs make interactive intervention possible. Actually it is the most up-to-date technique of small computer experimental systems. The interactive intervention by the operator provides him a possibility to choose from the alternatives offered by the computer according to the given situation.

MERCEDES is modular in construction so the user can organize a system satisfying other, special tasks even beyond the general-purpose system proposed by the program-package and the user-oriented programs. This is helped by dividing RTP into separate SNAP-s and by the subroutine-oriented construction of programs OLIP and OCAD.

The programs realize graphical display by alphanumerical characters.

These features make the process control program system MERCEDES suitable for handling various industrial processes and testing pilot plants, that is to perform tasks set up by technologists as regular services.

Summary

The general purpose process control program-package prepared for the portable computer laboratory designed in 1975 by the Automation Research Group of the Central Research and Design Institute of the Silicate Industry is briefly described.

Experiences gained in the portable computer laboratory during the software development are summarized as well. Finally, the general features of the process control program package are recapitulated.

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