

A PEARL-BASED MULTI-LOOP AND MULTI-SEQUENCE CONTROLLER

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The growing complexity of industrial automation systems is accompanied by the requirement for improved system dependability.

From this point of view, when designing distributed, hierarchically organized automation systems, some high-level languages have to be used not only for software implementation but also for software design.

Although the use of high-level programming languages for higher hierarchical levels is standard, this is not the case at the field-level where programmable controllers are placed, allowing the block oriented definition of closed-loop and sequence-controllers. Furthermore, a transparent multi-tasking software implementation is mostly missing.

On the other hand, the real-time process-oriented automation language PEARL and its extension Multicomputer PEARL represents a standard allowing the scheduling of concurrent closed-loop and sequence control tasks for distributed systems in a very transparent way. The degree of transparency, achievable by its module concept, as well as its high-level multitasking and process-I/O concept, recommends PEARL not only for software implementation but, as well, for software design. A PEARL-oriented software design will also improve software dependability significantly, if it is systematically transformed to another implementation language wanted, e.g. the language C.

In this paper, a controller will be described that can be graphically configured and parametrized. The controller software has been designed in a PEARL-oriented way and has been implemented in PEARL as well.

The system allows in a conceptually fully consistent way graphical, block-oriented configuration of closed-loop and sequence controllers being realized as independently scheduled tasks of programmable sample-time and interrupt, respectively. Control and sequence tasks can be mutually dependent via the process-I/O, and synchronized via RECEIVE/TRANSMIT communication blocks.

1. INTRODUCTION

State-of-the-art of multi-loop controllers, realizing cyclically execution of quasi-continuous or sampled-data control algorithms, is the block-oriented controller configuration with respect to standard function blocks of a library of control functions. The configuration can be carried out by command sequences and, more easily, by direct graphical input of the corresponding block diagram. Frequently called programmable controllers, only a few of them are transparent to the user with respect to multi-tasking performance [1].

On the other side, software transparency and software dependability can be improved by introducing software design with respect to high-level real-time language PEARL [2,14,15]. Therefore, a prototype programmable controller of the Institute of Automation of the University of Bremen [1] has been re-designed in a PEARL-oriented way, using its modular and high-level multi-tasking features [3,4]. Furthermore, the implementation, being in principle a systematic transformation to the implementation language chosen, has been performed here, most advantageously, in PEARL as well.

Modern programmable controllers have to offer the configuration possibility for both, closed-loop and sequence-control. In most cases, both types of configuration cannot be consistently applied and concurrent execution of sequence-control tasks is not available. This situation has led to programmed versions of sequence-controllers, again, adapting the capabilities of real-time languages [5]. On the other hand, having designed a programmable controller for concurrent closed-loop control tasks in PEARL, this design can easily be extended for configuration of concurrent sequence-control tasks. This strategy has been chosen by the Institut of Automation based on the well-known standard function-plan [6], in order to avoid additional compilation for graphical input [7]. The same argument holds if the more abstract Petri net oriented function chart [8,9,10] would have been used.

Instead of conventional cyclic scheduling, sequence-control tasks can now be transparently scheduled on interrupt with respect to digital input changes [11], minimizing the processor load by these tasks. Furthermore, software design is easily extended for communication function blocks [12] based on Multicomputer PEARL [13].

2. SOFTWARE DESIGN

Concepts of realtime process-oriented language PEARL [13,14,15] recommends itself not only as a software implementation language but also as a software design language for real-time problems. Therefore, the so-called PEARL-oriented software design has been introduced [2] combining the features of PEARL with graphical tools of modern software engineering. PEARL-oriented software design comprises two design levels: design in the large on the higher level and design in the small on the lower level, respectively.

2.1. Design in the Large

On this higher design level the module architecture is defined based on construction of a special type of import graph. Modules are defined as abstract data structures, i.e. as collections of procedures, tasks and data, having a well-defined import/export interface. Im-

ports are only allowed by higher level modules from lower level modules resulting in a very transparent module architecture, representing a module structure tree (Fig.1).

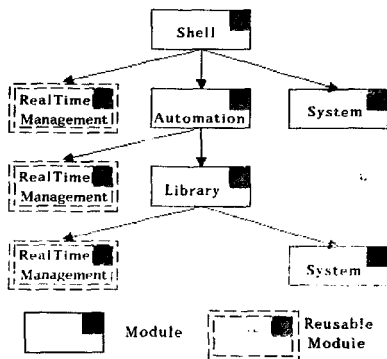


Fig. 1: PEARL-based module structure tree of the programmable controller.

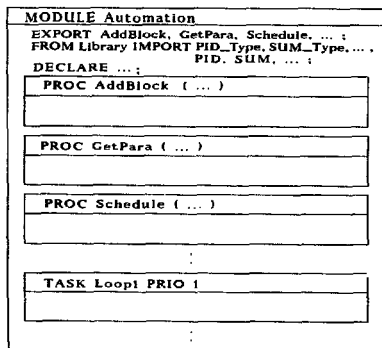


Fig. 2: Preliminary structogram (Nassi-Shneiderman) diagram of the module Automation.

Furthermore, transparency of the design is improved by definition of a separate system-

module for data-stations, representing the high-level process-I/O interface used in PEARL. Fitting to this concept, the real-time operating system is represented by implicit imports from pre-defined real-time management PEARL modules (Fig.1).

From the import graph defined, preliminary module structograms can be derived (Fig.2) after adjoining the exported procedures and tasks to the corresponding tree nodes. An important reason for choosing a tree structure for the import graph used is its property of having a very transparent correspondence to the function architecture of the lower design level, called design in the small.

2.2. Design in the Small

In the next phase of design structograms of functions (procedures and tasks) are constructed in the top-down direction accompanied by the design of a function structure tree. In Fig. 3 a typical function structure tree is shown corresponding to the module structure tree in Fig. 1. Note that the system module has no counterpart in this type of function structure graph and that the implicit references to functions of the module RealTimeManagement have been ignored, for convenience.

A central role plays the automation module

comprising the software images of controller tasks, function block data structures and corresponding access functions. The execution part of a controller task represents in principle an admissible sequence of library function calls, i.e. calls to numerical or logic library functions for closed-loop or sequence controllers, respectively.

2.3. Improvement of Software Dependability

Several features of PEARL have been used in software design for improvement of software dependability [2]. First of all, high level scheduling is used for closed-loop and sequence control tasks, i.e. cyclically with respect to given sample-time (e.g. *ALL Ta ACTIVATE Loop1*) and on interrupt (e.g. *WHEN DigInChange ACTIVATE Sequence1*), respectively. The interrupt DigInChange is stimulated by some digital input change.

Furthermore, the interface of function block procedures is defined by only one parameter, representing the function block data structure. The data structures are declared on module-level of automation module, comprising function block parameters and output, as well as input pointers to predecessor function block outputs. The pointers are defined by connection configuration and parameters by parametrization by exported access functions, avoiding completely the export of data structures.

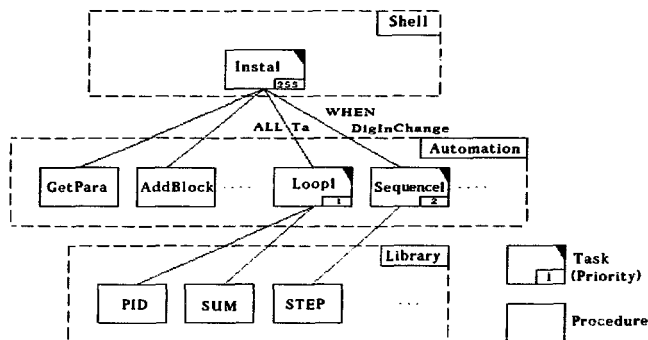


Fig. 3: Function structure tree of the programmable controller.

The technique of encapsulation can also be met for semaphores necessary for synchronization with shell tasks, e.g. for parametrization task with online running control task [2,3].

Finally, a very important feature is the extendability of PEARL-oriented design to multiprocessor and distributed systems. On the one hand, due to the potential parallelism of PEARL-tasks, software design is independent of the number of processors used. On the other hand, there is a fully compatible PEARL extension, i.e. Multicomputer PEARL, defining high-level design constructs for intertask communication via ports. Function blocks have been designed for communication with respect to no-wait-send and blocking-send protocol. The last one being the well-known communication by rendez-vous, this offers the possibility for synchronization of concurrently designed sequence control tasks. A typical application of communication function blocks is the data exchange with higher level stations for process observation and visualization.

3. SOFTWARE IMPLEMENTATION

The user can graphically configure a control-task in block diagram form from a higher-level station of a hierarchically organized automation system and by configuration commands from a local terminal, respectively. Among available library functions for closed-loop control there exist, e.g., functions for A/D- and D/A-conversion, PID-control, LS (least squares) parameter estimation and modern controller design. The function blocks for sequence-control tasks are compatible with the logical and step blocks of well-known function-plan [6], the connection to the technical process being configured via digital input and digital output blocks and with concurrent tasks via communication blocks (TRANSMIT, RECEIVE).

Typical graphical representation of a closed-loop and of a sequence-control task are given in Fig. 4.

Configuration, parametrization and task control by the user is menu-driven, the corre-

sponding menu-transition diagram being illustrated in Fig. 5.

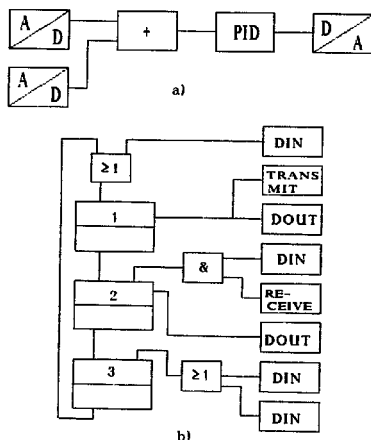


Fig. 4: Typical block diagrams for graphically configured closed-loop (a) and sequence (b) controllers (DIN: digital input, DOUT: digital output).

4. CONCLUSIONS

For the time being, the system will be extended to multi-level graphic configuration possibility of more complex controller specification, increasing system flexibility. For this purpose, configurations of standard blocks can virtually be defined as user function blocks to be used on next higher configuration level.

Due to the high portability of PEARL the software of the programmable controller has been easily implemented on various types of microcomputers (Motorola, Intel) and PC's as well as on a MC 68000-based single-board computer. It has been successfully applied to several automation systems, e.g. as a component in an A&R Testbed embedded system under support and in cooperation with Deutsche Aerospace/ERNO.

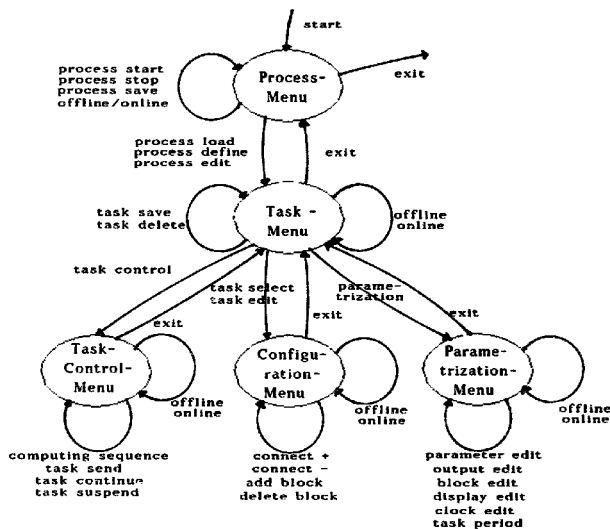


Fig. 5: Menu transition diagram of the programmable controller.

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