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Three-dimensional programming and simulation of PLC-controlled manufacturing systems

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Section: *Virtual Engineering*
Contents: *Software development for programmable logical controllers is usually based on low-level languages such as instruction list or ladder diagram. This classical method causes a lot of problems since this special view of the production systems to be controlled does not suit the people from different departments in charge. It is the aim of the paper to show a way of developing PLC-software graphically and interactively within a Virtual Reality (VR) based system.*

INTRODUCTION

Currently, the automization market is undergoing drastic change. Since the transition from fixed contactors and relays to free or programmable logic controllers (PLC) systems at the end of the Sixties, there have been no further dramatic changes /1,2/. After the breakthrough of standard hard and software from the mass market "Office PC" into the sector of automatization equipment which up until now had been dominated by manufacturer specific, hardware orientated systems, new chances have arisen for applications and providers, pricing systems have been overthrown and innovations have been possible /3/.

1.1 Problem outline

Over the past few years "Simultaneous Engineering" has become a keyword when developing new products and the associated production facilities. It represents the consistent parallelisation of planning processes and the continuous exchange of information between the members of a project team. On the one hand this reduces the period of execution considerably, on the other hand faults which occur during the early planning phases are discovered more quickly and then rectified. This is meant to save time and hence reduce costs.

When planning an automated assembly or production system, a number of tasks must be performed: In addition to the configuration of the system, programming the individual elements and the system as a whole is extremely important. Whilst production systems usually use NC programs, SPC systems are used in automated assembly and handling systems.

However, practice has shown that the intention of performing programming and testing of the PLC programs before the facilities have been constructed frequently fails due to the complexity of the task.. On the one hand this is due to the limited development and test tools of classical, interlocking programming methods and on the other hand it is due to the different views of the sections participating in the project (Fig. 1). This applies especially to the conflict between mechanical engineering and control engineering.

As a consequence, most of the programs are tested on facilities which have already been constructed.. It is at this stage that programming errors as well as discrepancies are discovered between hardware and software and this in turn delays initial operation.

A number of different investigations have shown that it is especially the software development of control technology which is responsible for a large majority of the errors occurring during this phase (Fig. 2).

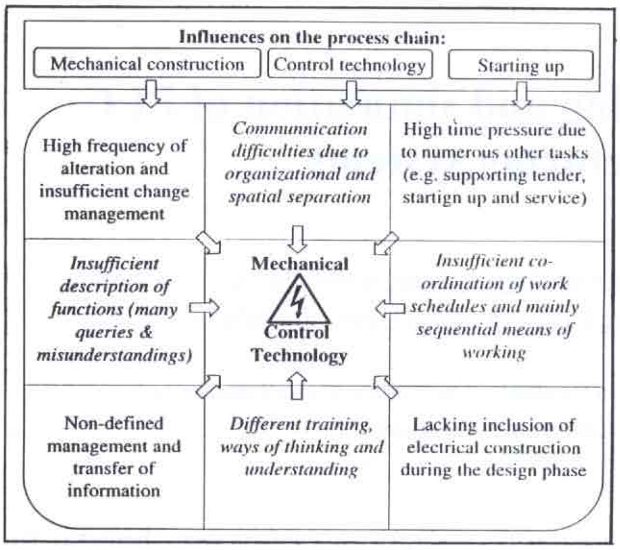

Fig. 1: Problems of sequential process chain for the planning and maintenance of PLC software in mechanical engineering businesses using the interfaces mechanical engineering / control technology / starting up as an example.

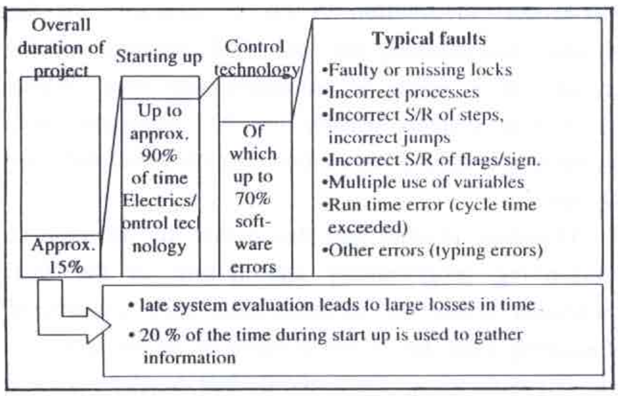

Fig. 2: Results of investigations into starting up analyses /4,5/

1.2 Demands placed on an integrating planning tool

Due to the immediate visual display and visualization and possibility of direct manipulation, the interfaces utilized by virtual reality technology have a high potential for motivation. However, because they are only two dimensional, these systems do have limits, especially as soon as a three dimensional representation becomes necessary or would at least be helpful in aiding the understanding of the task.. New approaches are therefore to be found in three dimensional models of the system.

Virtual reality systems make it possible to utilize man's natural problem solving behaviour to a far greater extent than with the user interfaces used so far. This has been made possible by the fact that the design of synthetic surroundings which are very close to reality and the possibility of three dimensional real time interaction always creates a relationship to real conditions. Hence the user is able to act intuitively or use his experience and is therefore able to cope with complex, three-dimensional problems without being inhibited by limitations.

Within the scope of the project "Innovative Technology and Systems for the Creation of Virtual Products", in short iViP, the Institute for Machine Tools and Production Science in Karlsruhe is working on a concept in parts 4.3 and 5.1 of the project which is to improve the PLC process chain with the deficits described above using virtual reality technology /6/. This is to be realized by providing an interactive system with the help of graphic representations of actions and switching conditions as well as simple user dialogues for logical connections. This type of representation which can be easily understood by everybody participating in the process chain, considerably reduces interface losses concerning the creation process of the system. The actual PLC code is generated automatically. The dynamic three-dimensional model with integrated control functions can also serve as a simulation environment. /7/

Coupling technological and control information to the three dimensional VR representation facilitates the re-utilization of existing software modules. Business sectors which come before the actual core sectors of the PLC planning (i.e. construction and control technology) such as, e.g., sales and those which come after these core areas such as e.g. starting up, are supported by VR communication and co-operation platforms. This enables co-operation without temporary or local restrictions.

2. REQUIREMENTS

The generation of error-free, executable PLC programs for automated production systems is an important aim of the planning process. In future, in the face of increasing pressure in terms of time and costs, testing and simulating PLC programs during the planning phase will become increasingly important.

Programming, testing and simulation environments available so far do not fulfil the increasingly complex, multi-dimensional demands placed upon the task of controlling and require the design of a completely new way of thinking in terms of generating software.

The aim of the current developments at the Institute is the design and development of a software tool which improves the process chain in PLC planning in the long-term. The VR methods used and the dynamic three-dimensional model should contribute to increase the quality of the software produced. This can be realized by means of a simplified programming method and the possibility of simulation of the processes at an early stage of planning, of paralleling the engineering process and hence also shortening the process. /8/

To achieve this goal, it is necessary to design a consistent data model as well as a simple, intuitive programming method which can be understood by all those sectors participating in the process chain. This enables a VR application for spatially distributed planning to be created using research results from network and communications technology.

3. DESIGN OF A VR SUPPORTED PLC PLANNING TOOL

3.1. Structure of the system and prototypical application of the planning tool.

The partial steps of planning and specification of VR supported PLC programs can be sub-divided into:

- specification of shape and other purely external features of components in the resource library
- specification of the basic functions of the components in the resource library
- interactive configuration of the system With the help of resource libraries
- logical connection of sensors and actors into functional modules with the help of graphical representations
- sequential coupling of functional modules to procedural modules
- transferral of the procedure generated in a control code
- simulation of control code in VR
- if necessary on-line coupling control / VR

Fig. 3 provides an overview of this. The model of the equivalent in the planning tool is currently realized using the commercially available VR environment AnySIM by Tecnomatix.

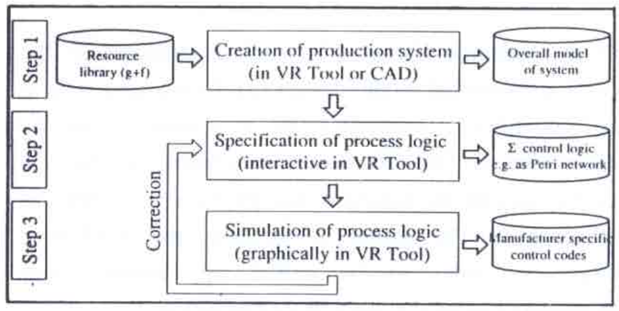

Fig. 3: Procedure for generating graphically interactive programmable logic controllers using virtual reality.

3.1.1. Modelling resources and structure of resource libraries

Due to the lack of three dimensional interfaces with CAD programs, the resources are modelled and structured in the VR environment. As a result there is a redundancy in the geometrical modelling. In the federal project iViP /6/ these problems are processed through the entire product development process chain. However, in the case of the model based on virtual reality, the information and function content of the graphical objects important specifically for planning can be dealt with in more detail. The aim is to reproduce the behaviour important for the generation of the PLC programs, i.e. for example the switching panel of proximity sensor or the effect of a pusher on pieces of workpieces or workpiece holders. In Fig. 4 this is described as the functional property of the component

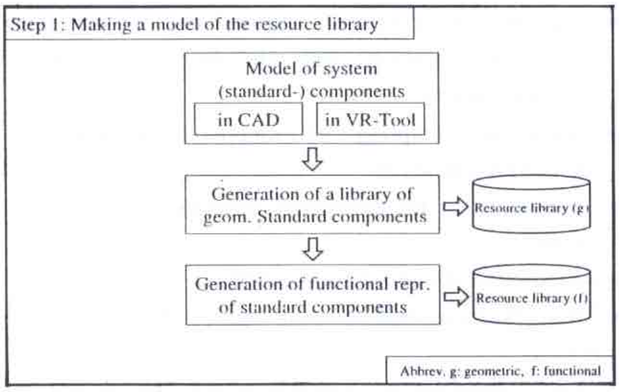

Fig. 4: Model of resource library consisting of sensors and actors (first geometrically and then functionally)

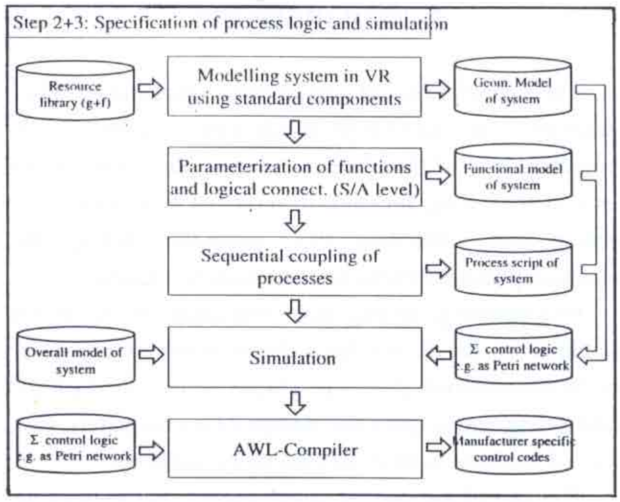

Fig. 5: Geometric structure of the production system from the resource library with logical connections.

for the resource library (f) which is adjacent to the purely geometrical model design (g). In the same way as the geometrical properties of a resource can be represented in limitless detail, depending on the VR system, so can the function and physical properties of the resource. The modelled resources are saved in a library in order to be called up, inserted and manipulated using the tools described below.

3.1.2.Specification of the sequence logic

After making parameterised components available in the library of control components, the system is put together in virtual reality and the components are arranged respective to one another. This is followed by the logical switching of individual sensors, flags and actors into small control networks which are then joined together to give the overall logic of system control (e.g. as Petri network), (compare Fig. 5). Depending on the task to be performed, sequential approaches such as unit chain programming or non-sequential approaches such as status graphs are possible.

Due to the ease with which it is analysed, a Petri network /9/ is used as a computer internal data model. This possibility of storing control logic can be recorded without a great deal of programming in the tables of relational databases. Using freely available algorithms, their deadlock freedom can be proven.

3.2. Function control of PLC software using simulation

The division between planning and simulation of software is no longer necessary thanks to the VR model described (geometry and process logic). The aim is an integrated environment where both on-line and off-line simulation has been realized. Fig. 6 shows the options which must be possible in parallel in order to guarantee greatest possible transparency and flexibility of the tools used and also in order not to limit the user to a single method:

Simulation 1

The procedure generated based on the visual

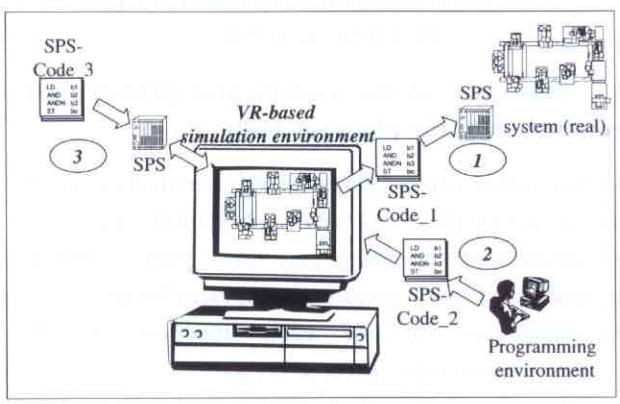

Fig. 6: VR based simulation

programming method is simulated and validated in the VR environment. A compiler converts the system internal procedure code into a language PLC understands.

Simulation 2

Programs generated using common programming languages are interpreted and executed by the VR model. Special interfaces and the high degree of interactivity with the model and functionality permit the simulation of operating modes such as "Manual" or "Tipp".

Simulation 3

A connection between the VR model and the PLC's I/O level permit a direct connection between simulation and PLC. At defined times, the PLC transmits a copy of the system to the VR model which then executes the actions. For the next cycle, the PLC reads the changed system status. Close co-ordination of cycle times of the PLC and program execution of the VR model is necessary. In the case of existing PLC programs it is also possible to directly influence the procedure, e.g. with virtual operating units.

3.3. Current status of the VR supported PLC planning tool

Currently, the tool developed at the Institute supports virtual reality environments by Tecnomatix (AnySIM) and by VRT (Superscape). The functionality of the programming interfaces of the software packages are very different and hence the PLC planning tools which had been developed adaptively also differ greatly. Application specific formats are used for the geometry and functionality of the control components. In the long-term these are to be replaced by a uniform data format. (3D-CAD model = VR model).

So far the functionality of the procedure has been proven using two prototypes /9/. Within the scope of the BMBF Project iViP, the tool will be developed further and refined. A wide data base (geometry and functionality) is to be created for the generation of a PLC controlled production system which makes it possible to build up the system using parameterised standard modules (compare Fig. 7).

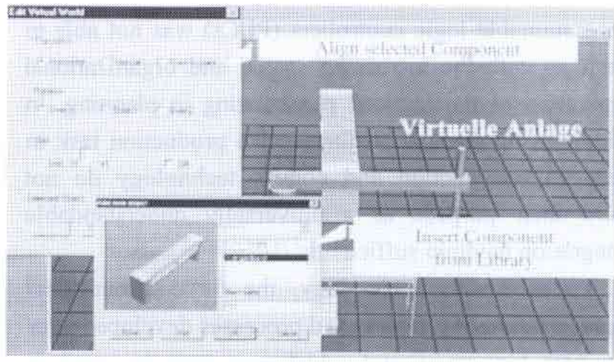

Fig. 7: Insert and align components from the library

In addition, controlling tasks such as virtual wiring together (Fig. 8) and switching components together (sensors and actors) is to be made more intuitive than before (Fig. 9).

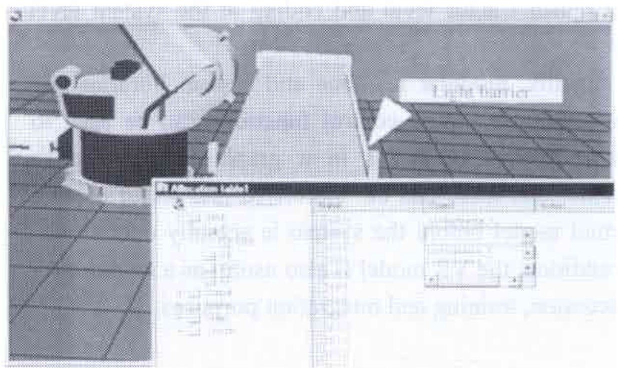

Fig. 8: Virtual wiring using a light barrier as an example

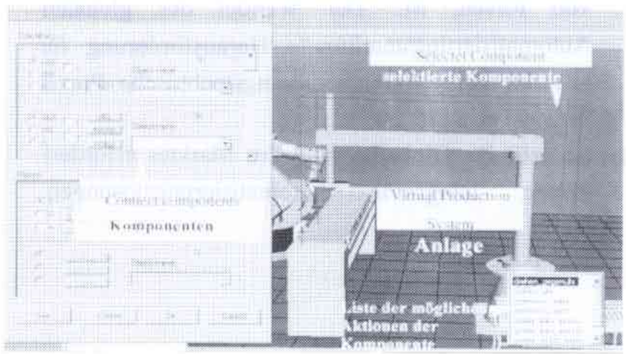

Fig. 9: Connect components (sensors and actors)

4. SUMMARY

The development of computer supported aids to design control systems and programming languages for programmable logic controllers (PLCs) was not able to keep up with the increasing spatial and organizational separation of the sections participating in planning. In addition, the description forms of a production task in between construction and control technology do not fulfil their purpose as a universally understandable integration medium sufficiently /10/.

Virtual reality technology, the three dimensional representation of products and processes developed over the past few years and which can now be used in practice, together with the possibility of interaction with objects and functions, represents a solution to this problem.

The aim of this paper is a programming method for PLC software based on graphical representations and interaction with objects. For this purpose, a hierarchically structured VR model is defined starting at the sensor / actor level and ending at the system level /9/.

Finally, modular resource and system libraries and the respective stored control functions can be used to create control programs in a graphically interactive manner and these can be simulated and tested using a virtual model before the system is actually operational. In addition, the VR model is also useful as a medium for discussion, training and integration purposes.

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