# Virtual Reality - An Approach to improve the Generation of fault free software for Programmable Logic Controllers (PLC)


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## Abstract

*Software development for programmable logical controllers is usually based on low-level languages such as the instruction list or the ladder diagram. At the same time, the programmer looks at a machine or an assembly system in a bit-oriented way; he translates the operational sequences into logical and/or time based combinations of binary signals described by the means of Boolean algebra. This classical method causes a lot of problems in reality so it should be improved. It is the aim of the report to show a way developing PLC-software graphically and interactively within a Virtual Reality (VR) based system (VPLC).*


## 1 Introduction

The process chain for the planning of PLC-controlled facilities gains more and more importance in companies of the mechanical engineering industry. However, in a company with an organizational division of tasks according to function, processes which actually intertwine are subdivided into partial processes that are often worked upon by „widely spread" specialized departments [6]. Therefore, information and communication problems typical for process chains as shown in figure 1 occur here, too.

A detailed analysis showed that the lack of a uniform and consistent consideration of the facility to be controlled emerges as one of the major reasons for software errors. To-date, any properties and features of the facility of functional relevance have to be determined from different sources (CAD drawings, part lists, component catalogues, verbal/formal functional descriptions), then processed and integrated into the software by the control technician. Simultaneously, the efficiency of the development and test tools is highly limited due to the classical connection-oriented programming methods [2]. Thus, at the interface between design and control engineering, a fracture in model making occurs which encompasses today the splitting up and at least temporary loss of information that was originally connected (figure 2).

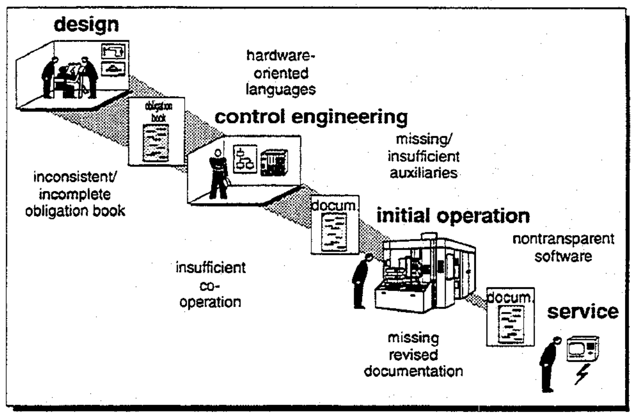


**Figure 1. Problems of the process chain for the planning and maintenance of PLC-Software in companies of the mechanical engineering industry**

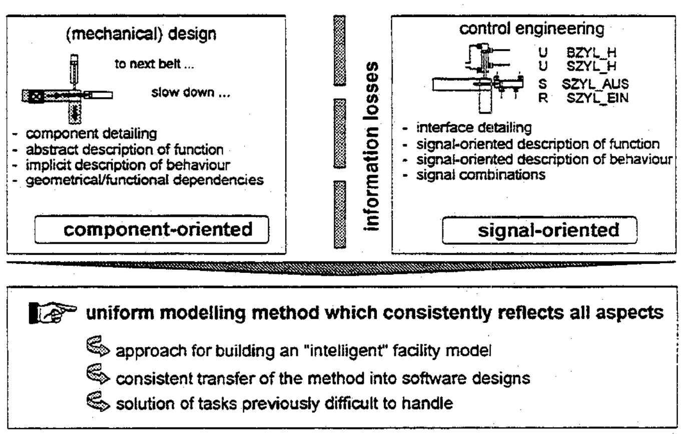


**Figure 2. Fracture in model making between design and control engineering**

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One of the decisive stages of realizing automated facilities is the stage of initial operation since only here the orderly interaction of the mechanical, electric, hydraulic/pneumatic functions and those of control engineering of a facility can be checked. Many errors, the reasons of which can be found in prior stages, are recognized only during the stage of initial operation. Apart from high costs they may also result in safety risks for man and machine.

Therefore an important work basis for the staff in commencement of operations - who are usually not involved in the planning phase but are often supported by staff members from design and control engineering - is a sufficient description of the facility [4]. Apart from the data provided in the technical description, a three-dimensional visualization of the facility to be assembled can prove to be a great support for the assembly staff.

Different research studies have shown that particularly control engineering and there again the software development can be held responsible for a major part of errors occurring during this stage (figure 3).

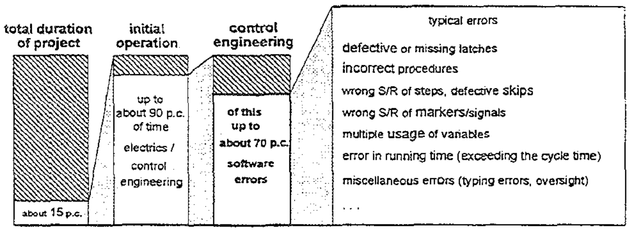


**Figure 3: Research results of analysis of the initiation of operations**

## 2 Solution approach

A solution of the above named problems in the planning of automated facilities, namely

- sources of documents are distributed and sections overlap
- information losses between mechanical engineering and control engineering
- staff in initiation of operations dispose of no spatial and functional comprehension of the facility
- software errors which cause great losses in time during initiation of operations
- no real graphic support, therefore no program evaluation in the development platform respectively in the projection stage
- complicated maintenance

is offered in the form of a uniform, integrated, computer-aided three-dimensional modeling of the complete facility including the implicit controlling task. However, the increasing complexity of the tasks in design, planning and production means that even the currently used methods of communication between man and computer have met with their boundaries.

Efforts to cope with this condition have led to the now extensive introduction of graphic user interfaces. These may mostly be used with the help of pointing appliances and they require far fewer abstraction skills and less knowledge from the user's part than the previous line or command-oriented surfaces did since they mostly use easy-to-remember graphic symbols instead of abstract commands. However, there are limits for the usage of these user interfaces as they are limited to two dimensions. It is particularly difficult to realize the handling of three-dimensional objects and working on problems which require a spatial representation.

New courses might be pursued by utilizing three-dimensional user interfaces the way they are realized in Virtual Reality systems. By using special input and output devices and computer platforms, these systems are capable of integrating the user or several users working in an interdisciplinary way (e.g. designer, layout planner, control technician) as the acting part into three-dimensional, synthetic environments which places the communication of man/machine and man/man onto a completely new basis [5].

With VR systems, much more use can be made of the natural problem solving attitude of man than was possible with previous user interfaces since it is always possible to refer to real conditions due to the real-life arrangement of synthetic environments and the possibility of 3D-interaction in real time. The user is therefore able to act intuitively or based on his experience and can thus also treat more complex spatial problems without being impeded by limitations.

This view complies particularly with the designer who assigns technical basic components or assembly groups to the partial procedures of the functional structure and then composes the facility layout. Each assembly group possesses not only its geometry but also determined physical properties, a logical or dynamic behavior and last not least relationships to other components[1].

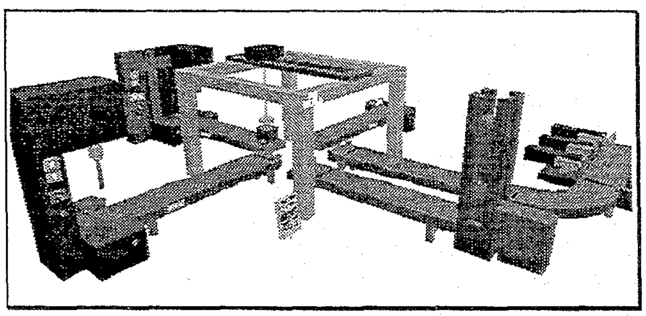

**Figure 4. Exemplary VR-model of the facility**

With the help of a function model, the basic procedures and connections within the VR system are described by the designer on a comparatively abstract level. Thus, on the one hand it represents the basis of an „intelligent" facility model together with the process model which may be regarded as a detailed and extended version of the function model, and on the other hand it is the basis of the subsequent PLC-program.

## 3 Representation of the object properties

The systematic classification of the components of a facility shows that certain characteristics are common to several or to all of the assembly groups considered. All facility objects, for example, have a setup structure and a defined geometry while stating a logical behavior is generally only possible for functional units or assembly groups with their own information processing or control objects. Figure 5 gives an overview over the attributes and properties required for the definition in control engineering of a technical object. The modeling method allows any desired expansions at a later time [7].

*Semantic data* serve to administrate the components. An essential item is the name of the component which will later facilitate unambiguous identification of the component type in any application.

*Geometric* modeling is done within the VR-System so far, but with increasing computer performance it will be possible to import complex components from existing data structures or from widely used CAD systems without the abstraction required so far.

Apart from the static (geometry) properties the dynamic ones of the facility elements have to be incorporated into the model.

Path-time or velocity-time diagrams used to be the standard to describe the conditions of movement and the movement profile. Attributing within the VR systems allows the description of direct physical properties such as initial velocities, friction, pulses, kinematics chains, or modified movement profiles as can be observed with pneumatic components. Therefore, collision studies can easily be carried out.

Each object is equipped with specific dialogues which are activated at running time together with the object. They serve on the one hand to facilitate communication between facility components and controlling, on the other hand also the exchange of messages of (intelligent) peripheral assembly groups among each other.

To improve the handling of complex object and data structures, VR systems are equipped with additional functions attractive to the sensory tract of man, such as texture mapping and sound.

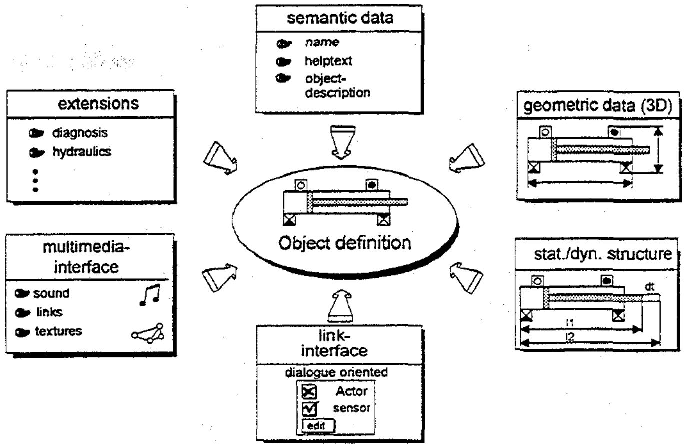


**Figure 5. Definition of a data record to describe an object**

## 4 From the objects to the PLC PROGRAM ready to run

The following partial steps and task areas may be principally differentiated when planning VR-aided PLC programs.

### 4.1 Configuration of the facility components

Using the working materials library and choosing from suitable menus (figure 6), the designer can load his facility modules, such as functional units (conveyer belts, pushers, linear axles), sensors (light barriers, limit switches) or even complete machines into his digital environment by clicking the mouse to „drag and drop". Apart from the geometry, the components are also furnished with certain basic functionalities corresponding to the data concept described above.

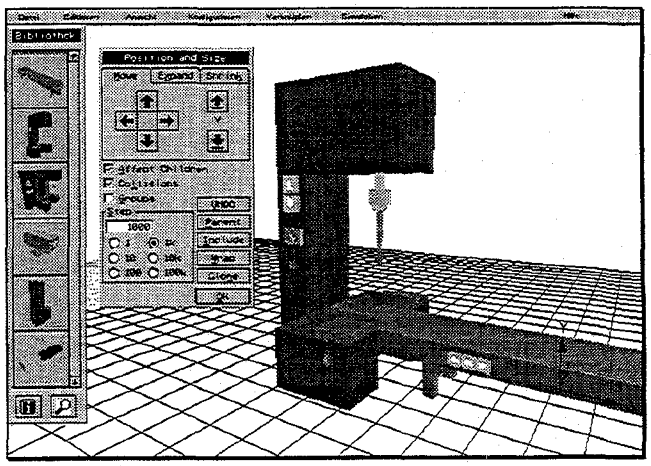

**figure 6: Configuration of the facility layout**

With the help of a corresponding input device, such as a spacemouse (6 degrees of freedom), the user may freely navigate within the facility and can thus validate the layout. With the corresponding tools the facility layout can be adapted to different requirements at any time.

## 4.2 Logical-functional connection

Inlets and outlets (actors and sensors) are connected to become action modules by choosing easy-to-remember graphic representations of actions which reflect a „1 to 1" image of the mechanical elements in the real world.

Choosing the actions activates a dialogue which facilitates a „bonding" of the modules in the VR system in a graphic, interactive way with a low level of abstraction. Any complicated construction of relationships and restrictions in instructions list, ladder diagram or contact plan is redundant.

On confirmation the dialogue is valid and represents a functional module; the graphic representations are colored to mark „connection".

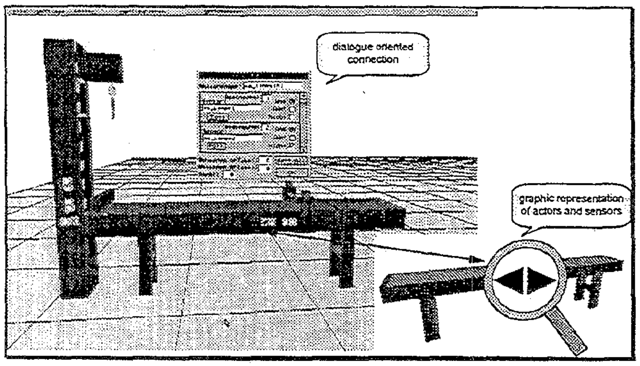


**Figure 7: Dialogue-supported programming of function units**

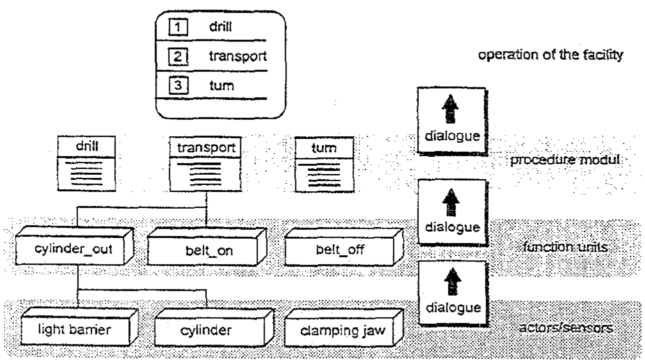


**Figure 8. Aggregating the complete facility from the modules**

The logic of the functional module and thus even at an early stage parts of the PLC-program may be tested by simulating the partial procedure.

In the next step, the functional modules are connected to become procedure modules, again with dialogue assistance. If arranged in sequence, these modules show the procedure of the facility. This hierarchically structured „bottom-up" approach is depicted in figure 8.

Upon completion of the programming, the facility is simulated taking into account aspects of time and geometry (collision). Errors, inconsistencies and weak spots are quickly recognized and eliminated due to the provided options of graphic representations, interaction and navigation within the digital model. Partial steps may be tested at any time, e.g. by resetting the tool manually in VR.

In the background, suitable transfer records according to DIN IEC 1131 [3] are issued. They can be translated into the different PLC dialects depending on the employed controlling. Apart from the mere control engineering, the layout plan, component and parts list may also be generated from the digital model.

# 5 Outlook

The project VPLC is currently being realized at the Institute for Machine Tools an Production Science at the Technical University of Karlsruhe, Germany. With the integrating platform and interface VR, not only the pure planning of the facility and the PLC-program generating but also planning of hydraulic systems, monitoring, diagnosis and failure detection based on an intelligent model will be part of future research activities.

# 6 REFERENCES


[1] Guinand, P., Planning of production sites with the help of Virtual Reality Exemplary Realization, diploma thesis, Universität (TH) Karlsruhe, 1995

[2] Schelberg, H.-J., Objectoriented Planning of PLC-Software, Dissertation Universität (TH) Karlsruhe, faculty of mechanical engineering, 1994

[3] IEC1131 Part 3: Standard for programmable controllers - Programming Languages, Beuth Verlag 1993

[4] Lanza, M., Schellberg, H.-J., Object Oriented Planning of control techniques, proceedings of „4. Fachtagung zum Entwurf komplexer Automatisierungssysteme", Braunschweig , June 7-9. 1995, p.463-468

[5] Osmers, U., Visualising, animating, simulating - Virtual Reality makes your plannings alive., IHK-Informationen für die Wirtschaft, 9/95, p.17-19

[6] Ritter, K.H.: process chains in product development, VDI-Breichte Nr.830, 1990.

[7] Spath, D., Osmers, U., Weber, J., Planning Production Systems with VR, DFG-Schwerpunktsprogramm, Ergebnisbericht der 1. Antragsphase, July 1995