

**VIRTUAL ENGINEERING:
VIRTUAL METHODS IN PROGRAMMING AND SIMULATION OF PROGRAMMABLE LOGIC
CONTROLLED MANUFACTURING SYSTEMS**

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Abstract: Software development for programmable logical controllers (PLC) 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. The VR-model can be used to simulate the PLC-Code and allows different dislocated users to work in a co-operative way.

Keywords: programmable logic control, PLC, simulation, virtual reality

1 INTRODUCTION AND PROBLEM OUTLINE

Over the past years “Simultaneous Engineering” has become a keyword when planning new products and the associated production facilities. It represents the consequent parallelisation of planning processes and the continuous exchange of information between the members of the project team. On the one hand this reduces the period of execution considerably, on the other hand faults, which occurred in the early planning phases are discovered more quickly and then rectified. This saves both time and money.

However, practice has shown that the intention of performing programming and testing of the PLC programs before the facilities is constructed 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 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 but can also be

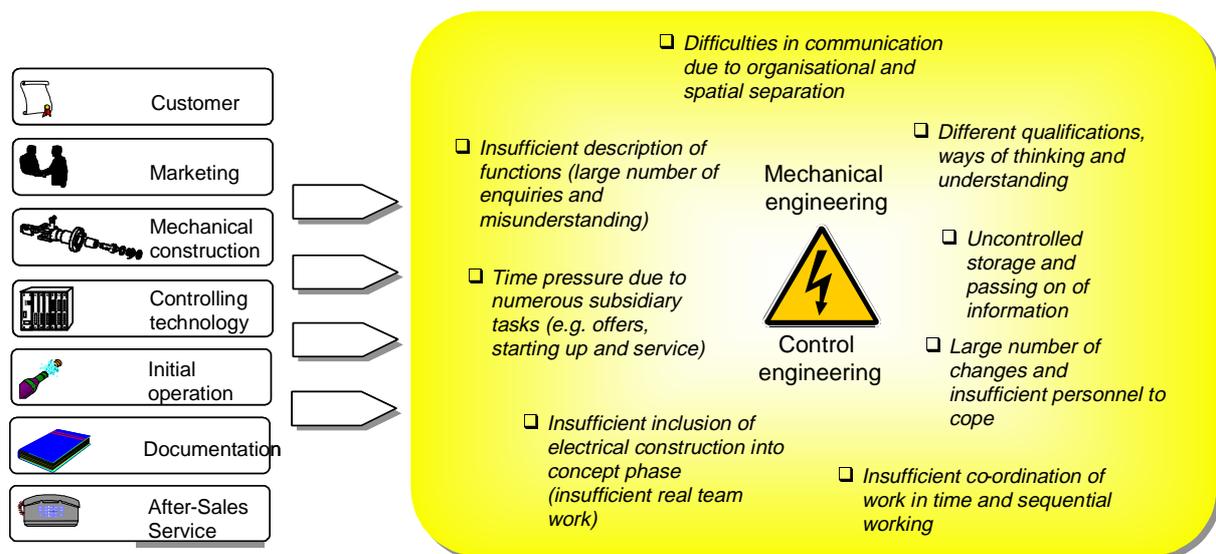


Figure 1: Problems of a sequential process chain for the planning and maintenance of PLC software in mechanical engineering companies using the interface construction/ control engineering as an example.

applied to any of the other specialized departments (e.g. marketing and initial operation). This leads to most of the programs being tested on the facilities which have been constructed by this time. Now programming errors and discrepancies between hardware and software are discovered which in turn delays initial operation.

1.1 Solution approach

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

- distributed and overlapping sources of documentation
- loss of information between mechanical engineering and control engineering
- non-existent spatial and functional understanding of the facilities by the staff responsible for initial operation
- software errors which cause great time losses during the initial operations stage
- no real graphical support, therefore no program evaluation in the development and planning phases
- complicated maintenance

is provided in the shape of a uniform, integrated, computer supported three dimensional model of the complete facility including the implicit controlling tasks.

Efforts to cope with these circumstances have lead to the now virtually complete introduction of graphic user interfaces. To a large extent these can be operated using pointing appliances and require far fewer abstraction skills and knowledge on the part of

the user than the previous line or command-orientated surfaces as they mostly use easy-to-remember graphic symbols instead of abstract commands.

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

This view is particularly advantageous for the designer who assigns technical basic components or assembly groups to the partial processes of the functional structure and then composes the layout of the facility. Each assembly group possesses not only its geometry but also fixed physical properties, a logical or dynamic behavior and last but not least a relationship to other components.

With the help of a function model, the designer describes the basic procedures and connections with the VR system 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.

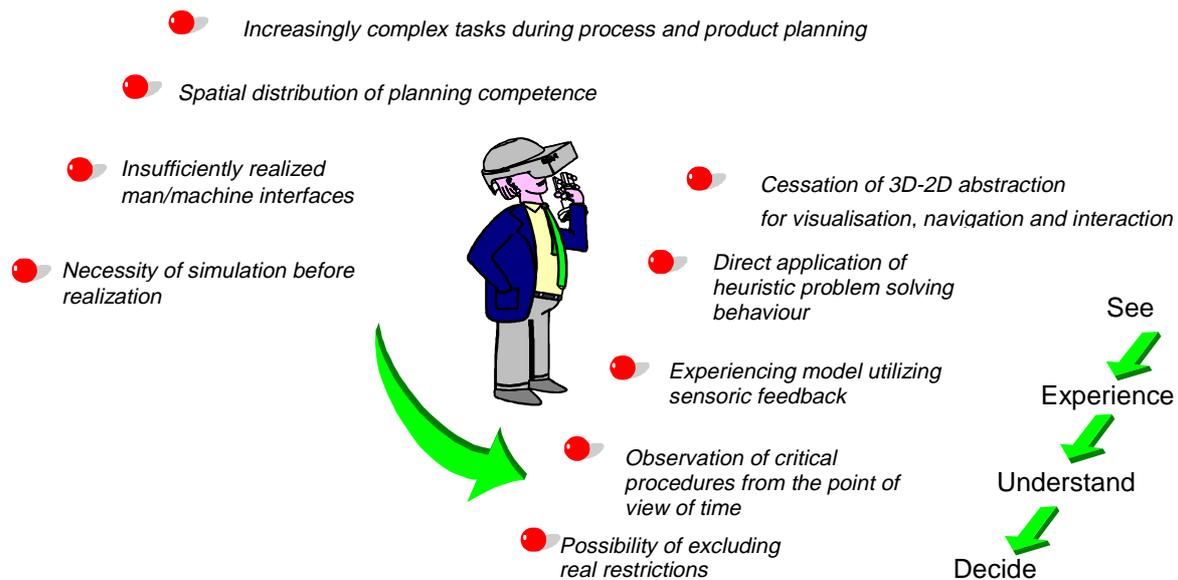


Figure 2: Advantages of VR interface.

2 VR BASED MODELLING OF GEOMETRY AND CONTROL LOGICS

With the introduction of defined classification levels of a machine, the modularisation of the overall machine function as well as the introduction of function descriptions including controlling tasks, the functions to be performed can be described a long time before the detailed technical solution. This makes it possible to provide functional information at such an early stage in order to fulfil the requirements of Simultaneous Engineering.

Modelling the components in a three-dimensional environment and the implied description of their motional functions makes the simple observation of the motion and collision behaviour possible. The VR program works through the cycle of input and output parameters and commands in a similar way to a PLC program. The speed with which conditional changes are executed is proportional to the picture repeat rate and should not be less than 20 pictures per second.

One can distinguish between the following partial processes and task areas when planning VR-aided PLC programs:

First the facility is compiled with the help of working materials catalogues. In the next step the logical connections between actors and sensors are produced using graphic, interactive programming technologies. Prior to final realization the configuration of components (geometrical aspects) and the functionality of the procedure control (logical and time-related dependencies) can be validated and optimized in simulation runs. The final program is transferred directly to the real facility via suitable interfaces. A direct coupling between the controlling

system and the VR system means the visualized 3D model can be utilized for process visualization and

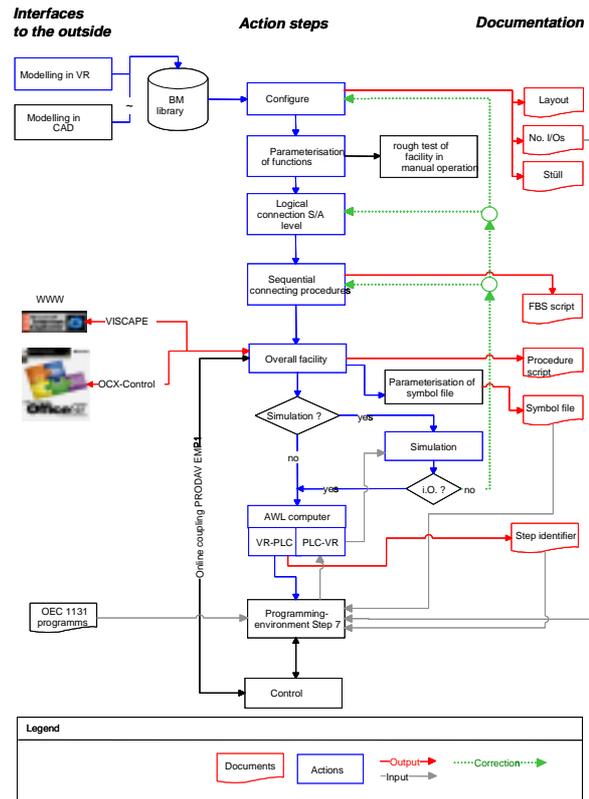


Figure 4: Structure of the system.

diagnostic purposes. Integrating the functionalities in the WWW opens up possibilities of documentation and utilization as a training and educational tool.

2.1 Configuration of facility components

Using a working materials library the designer can load his facility modules such as functional units (conveyor belts, pushers, linear axes), sensors (light barriers, limit switches) or even complete machines into his digital environment from suitable menus by clicking the mouse to “drag and drop”. Apart from the geometry, the components are also provided with

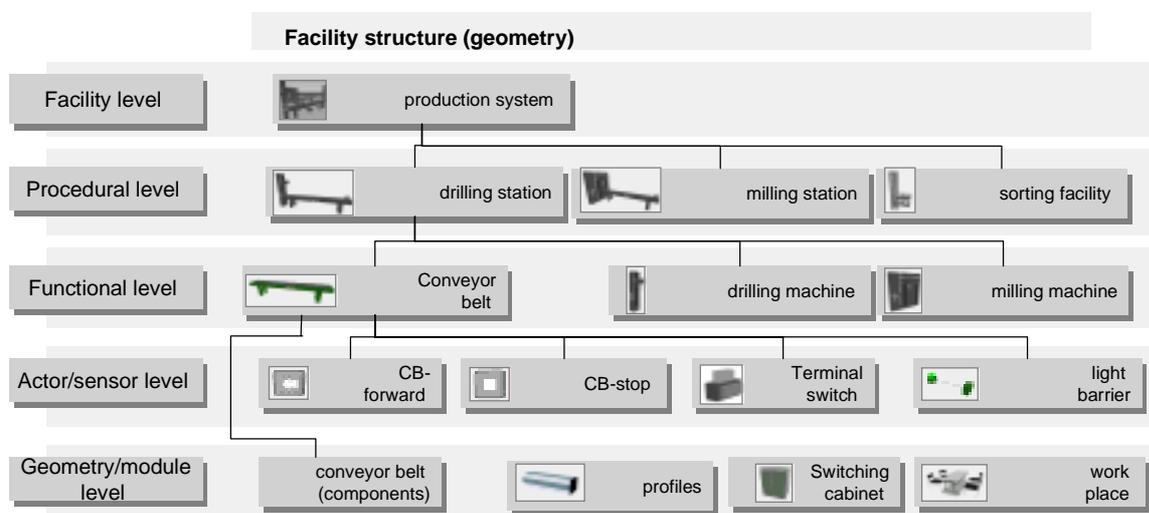


Figure 3: Aggregation of a technical system in the VR system

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| |M      Falschertechnikmodell
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| |*** Einrichten des Profibus ***
| |L      M -E20,0; * Koppeladresse fuer Profibus-DP
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| |UN      B -M_RESET; INITIALISIERUNGSBAUSTEIN. WIRD NUR AM ANFANG BEARBEITET
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| |SPS - Editorprogramm Version 3.20 (c) 1987-93 Robert Bosch GmbH

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Text PLC programming (AWL, KP, FP)



Intuitive connection of inputs and outputs in VR

Figure 6: Conventional programming versus VR interface and visual programming.

certain basic functionalities corresponding to the model. The system automatically allocates working materials with a unique variable as soon as they are copied or generated. This means that duplication is impossible.

With the help of the appropriate input device, e.g. a space mouse (6 degrees of freedom), the user can navigate freely within the facility and thus validate the layout and manually test the facility. The facility layout can be adapted to suit different requirements at any time.

2.2 Logical-functional connections

Virtual Reality provides the possibility of connecting control inputs and outputs (actors and sensors of the facility) to functional modules by selecting easy-to-remember graphic representations of actions which reflect a “1 to 1” image of the mechanical elements in

the real world . This concept of graphical representation makes programming the previously configured facility possible without prior knowledge of PLC specific languages.

Selecting actions activates a dialogue which facilitates the “bonding” of modules in the VR system in a graphic, interactive way with a low level of abstraction. Complicated construction of relationships and restrictions in instructions lists, ladder diagrams or contact plans is redundant.

2.3 Using simulation to check the functions of PLC software

The aim of a software test using simulation is to guarantee error free software when the facility is started up as any subsequent changes at this late stage must be made under a great deal of time pressure and

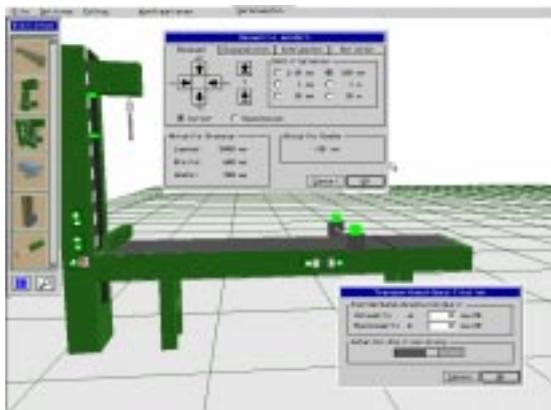


Figure 5: Configuration of the facility layout.

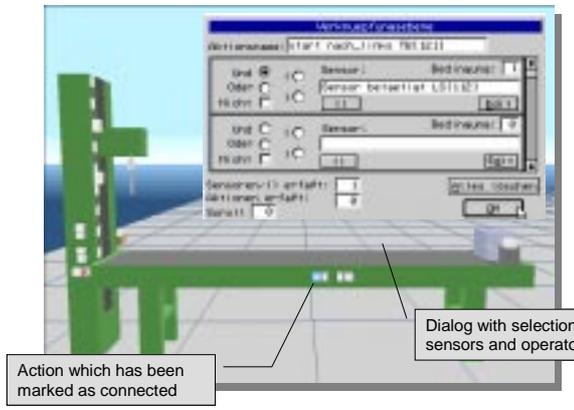


Figure 7: Dialogue supported programming of PLC functionalities.

cause anger and extensive costs. The demands placed upon a test environment are:

- a machine model which is as close to reality as possible
- simple and correct model creation
- the simulation procedures must be easily influenced
- reproducible test cases
- real-time abilities
- simple error recognition
- transparent visualisation of the simulation

The separation between planning and simulation of software becomes redundant thanks to the VR model. An integrated environment within which both on-line and off-line simulation has been realised is aimed at. Fig. 8 shows the options which must be available in parallel in order to guarantee the greatest possible transparency and flexibility of the tools used and to ensure that the user is not restricted to only one course of action:

Simulation 1

The procedure generated based on the visual programming method shown here 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 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 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 the cycle times of the PLC system and the 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 SUMMARY AND OUTLOOK

Virtual Reality as an advanced man/machine interface together with the increasingly powerful computers provide a virtually unlimited potential for future technical applications. The project introduced here is currently being realized at the Institute for Machine Tools and Production Science at the Technical University of Karlsruhe in the department of production informatics and quality management and subsidised by the German Research Association within the framework of the “Modelling production” programs.

Using the integrating platform and interface Virtual Reality, additional application areas, which are based on the applications presented here, are created in addition to facility planning and pure PLC program creation:

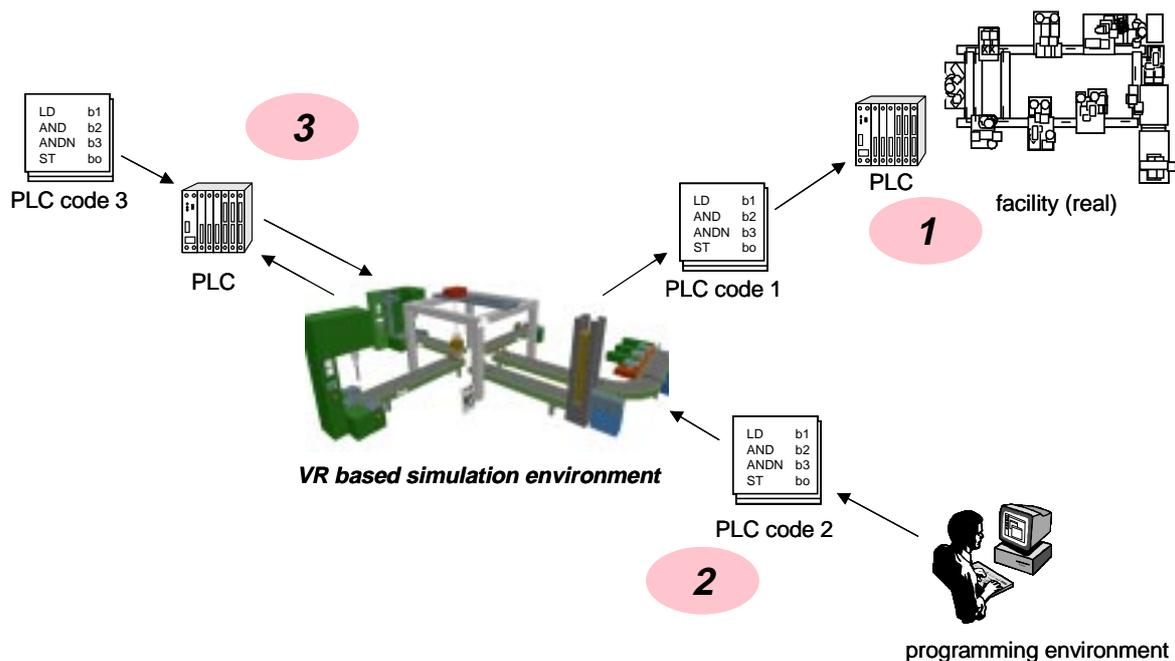


Figure 8: VR based simulation.

Inclusion of the method in existing DP environments

Certain software products have become established for the generation of products and process models. The appropriate interfaces must be created to utilize these models for PLC planning .

Interaction between NC and PLC

The approach presented is suitable for production systems consisting of assembly and logistics which can be configured based on modules. However, many PLC controlling systems in the manufacturing environment have been integrated into tooling machines and are closely connected with NC functions (adaptation control). In these cases, the concept must be extended accordingly.

Utilization of models for telemanufacturing

Modern controlling concepts facilitate the connection to telecommunications networks to permit access to machine controls across a distance. Both programs and data can be transferred and queried. However, teleservice applications go beyond this: the communications support for servicing is decisive. The integration of video and VR to support speech barriers are used as are e.g. on-line access to multimedia technical documentation based on the WWW. If the appropriate technology is available, it only makes sense to extend the teleservice functions to process control to telemanufacturing.

Generic PLC programming

Complete modularization of products and processes as well as their object orientated description and representation in a dynamic interactive 3-D software environment leads to the vision of generic planning of process control. Explicit programming of PLC becomes redundant, control commands and conditions for real facilities can be derived directly from the virtual model.

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