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OBJECT ORIENTED DESIGN OF NC PART PROGRAM SIMULATION SOFTWARE FOR VIRTUAL MANUFACTURING

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ABSTRACT

Virtual Manufacturing is a concept of executing manufacturing processes in computer environment as well as in the real word. This paper deals with the NC programming verification processes. It describes the main levels of simulation tasks.

The second part of this paper focuses on the object oriented modelling and simulation architecture for simulation of NC machining operation. In this area some new results will be presented.

KEYWORDS: NC programming, simulation, Object Oriented, Virtual Manufacturing.

INTRODUCTION

Virtual Manufacturing system is defined as a computer system which can generate the same information about manufacturing system's structure, states and behaviours as we could gain in a real manufacturing system. Driven by rapidly expanding Information Technology, especially virtual reality and the need by manufacturers to minimize part development time and costs and improve quality VM have progressed significantly. Virtual reality techniques have became increasingly popular in representing physical objects.

VM is a computer based model which represents the physical and logical scheme and the behaviour of real manufacturing systems.
Virtual Manufacturing provides the following benefits:

- It can be utilised to verify the operations in the production through virtual systems
- Based on actual production processes it can support generating more reliable estimates of production time, costs, quality
- Production time, costs, and quality can be predicted for supporting the decision making process of manufacturing management.

MODELLING AND SIMULATION

VM relies trough modelling and simulation technology to simulate all the necessary manufacturing activities by computer support technology to enable making it virtually. Modelling and simulation technology is an essential tool for VM systems that the manufacturing should be more flexible, as well as of high efficiency and quality. This paper focuses on simulation of NC machining operation. The main issues of simulation tasks are as follows:

- Syntactic verification
- Semantic analysis
- Geometrical undercut and collision test
- Tool life simulation
- Complex technological simulation.

Most of the up-to-date NC programming systems involves some kind of simulation. The input of this simulation is CL-Data or other data format representing geometrical and technological information. There are also stand-alone simulators manipulating post-processed NC program in ISO format.

The syntactical verification is based on the lexical description of the NC program language used. During semantic analysis, certain tool path degeneration can also be detected.

Recognition of undercut and collision events also requires investigation and evaluation of the geometrical model of the part and the actual tools.

SOME NEW TASKS FOR SIMULATION

In VM systems there are many functions related with time information. One of the most important factor is connection between *make-span* and *operation times*. A new area of pragmatic verification of NC part program is the analysis of operation times on cutting conditions. To achieve the objectives (goals) of production the operation times must be known Computing of the operation time is the basic service of the modern simulators. The operation time is a function of the tool path generation method. By means of simulation some different versions can be tested, and the optimal method can be selected. Considering the term of average or extreme program running conditions the technology bottlenecks of the manufacturing process can be identified. At the bottlenecks, the *cutting intensity* must be increased. The operation time is the sum of machining (or: main) time and auxiliary times:

$$t_{op} = t_m + \sum_i t_{a,i} \ . \qquad (1)$$

The effect of the NC override of cutting is that the operation cost change in a non-linear way. Because of the increased cutting intensity, the tool life decrease. It causes more frequent tool or cutting edge change. Balancing the machining and tool cost is an optimal finding problem. My research topic is to develop a new NC program simulator which can support process planning and scheduling optimization.

The complex technological simulation includes the simulation of quality assurance and quality control as well.

The major factors affecting quality are as follows:

- force
- vibration
- quantity of heat
- tolerances
- deviations
- surface roughness.

All of these factors can retraceable to elementary volumes and integration of these. The simulation of quality assurance can be executed on this. This requirement introduces a new generation of simulators.

An inverse approach is to use NC part program simulation when geometrical and technological information are gained from archive NC part program. The purpose of this can be:

- verification of the correctness of a part program,
- modification of the existing part program generating a new version,
- detection of collision, break, waste, etc.

In this case simulator supports the Virtual Shopfloor or machining cell dispatching in direct way by using the devices libraries and other simulation service modules.

SOFTWARE TECHNOLOGY FOR ADVANCED SIMULATION

Development of a VM software is a complex problem. Factory equipment and materials, parts and products and attached information should be defined as an object class in a hierarchical model library. VM should give a framework which covers simulation.

As research work of latest year I have developed a simulator for NC machining operations. The most important step of the object oriented design is to build-up the object hierarchy. The nature of simulation problems is that the processes temporal proceeding is examined. From a software technological point of view simulators are aggregations of static and dynamic objects. Such a static object is the simulator object. This is the central object of the simulation. It contacts the auxiliary objects for example the user interface object, and manage the graphical animation.

Other object can arise only dynamically, in runtime. The object of simulation should only be dynamic objects. During the object oriented design I have made up a hierarchy of class to decompose the NC program into sequence of entities. Such entities are the movement cycles (fast feed, linear interpolation, circular interpolation), coolant, spindle on/off and even the end of the sentence sign. The entities visualization one after the other results the graphical animation. The ability of object's polymorphism is observable in this example. The visualization method of the object coolantOn different to the object linearInterpolation. The main purpose of the graphical animation is semantic analysis. The use of the object oriented technology makes it possible to imply additional simulation levels without modifying the code. Unvarying existing interfaces of the existing, well written objects the software can be extended adding further interfaces and components.

A significant problem of simulator software is graphical environment. Developing a new standalone graphic library is a notable task. It can not be a part of development of the new simulator software. The basic graphic libraries only supports elementary 2D objects. This is the code reusing. Performance of the modern computers permits the use of real time 3D animation. The OpenGL graphical library regards as a quasi standard in this area. It is accessible to most of the operating systems. To improve performance, some of the video accelerators support hardware OpenGL acceleration. An other possible and popular method is using the Virtual Reality. The Virtual Reality Modeling Language is standardized, platform-independent and suitable for network.

In the course of developing a simulator software the network environment must be examined. The access of tools database and download of the NC programs from the DNC server are through network in the real machine tools environment. The simulator must be equipped with the ability of sending and receiving standard manufacturing messages, accessing databases, communicating with other computers. Real time processing for advanced VM systems should have distributed simulation.

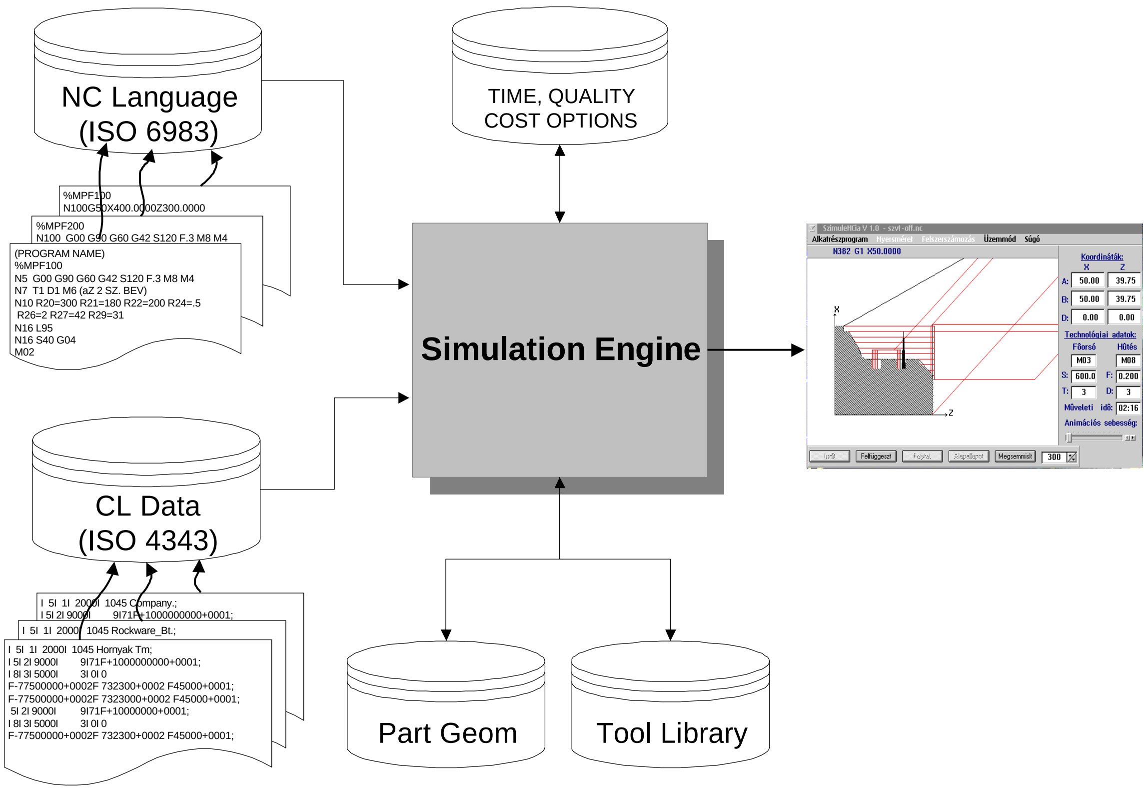

Fig. 1. Simulator for graphical verifications of NC part program

CONCLUSIONS

The widespread adoption and implementation of VM will be in intermediate term. Requirements set against the simulators have recently been increasing. The simulators having multiple services support multiple CAxx functions, for example CAPP, NCP, PPS, etc. Developing a complex simulator for Virtual Manufacturing requires object oriented technology.

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REFERENCES:

[1] Iwata, K., Onosato, M., Teramoto, K., Osaki, S.: **„A Modelling and Simulation Architecture for Virtual Manufacturing Systems"**, Annals of the CIRP, 44, No. 1, pp.399-402.
[2] Onosato, M., Iwata, K.: **„Development of a Virtual Manufacturing System by Integrating Product Models and Factory Models"**, Annals of the CIRP, 42, No. 1, pp.475-478.
[3] Monostori, L., Kádár, B., Egresits, Cs.: **„Virtual Manufacturing Using a Hierarchically Coupled Hybrid AI System"**
[4] Avgoustinov, N.: **„Virtual Shaping and Virtual Verification of NC-Programs"** (Simulation of Part Manufacturing by Means of NC Machines in Virtual Reality)
[5] Dominic S. Guevarra: **:„An overview on Virtual Manufacturing Systems"**
[6] TÓTH T., ERDÉLYI F.: **„The Role of Optimization and Robustness in Planning and Control of Discrete Manufacturing Process."** The Second World Congress in Intelligent Manufacturing. CIRP Budapest, Hungary, 1997., pp. 205-210.
[7] Hornyák, O.: **„NC program ellenorzo szimulátor fejlesztése"**, 1997