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NC-/RC-Programming based on object-oriented models

Abstract:

Adapting existing NC- or RC-programs to changed requirements, such as different machine tools or robots or tools, is time-consuming and expensive. The machine-oriented generation of NC-programs prevents a flexible distribution of partial machining tasks to the suitable machine tools currently available.
A newly developed machining model based on machining objects, which can be applied to several manufacturing technologies, is presented by a flexible user-oriented NC-programming method. All the objects are described by using the STEP-Toolkit currently available.
By using such objects for programming more information is provided at the control system and the machining process is made transparent. Furthermore the modification of the generated NC-programs becomes more comfortable by interacting directly with the corresponding graphical model based on the ACIS-kernel. The user is supported by an interactive graphical user interface. Similar ideas can be applied with RC-programming.

1 Introduction

The process sequences used so far for the definition of machining a workpiece by means of a numerically controlled machine tool are shown in fig. 1.1. Essential characteristics are on one hand the uni-directional arrangement of the process sequences and on the other hand high loss of information due to the given interfaces. Especially the DIN 66025 which is used for data exchange between the NC-programming and the numerical controls applied in manufacturing should be examined carefully and re-evaluated as well as re-defined, if the new open and user-oriented concepts for control systems are to be a success. This applies equally to programming industrial robots (IR).

The following article describes the deficiencies of the existing DIN 66025 as found in various companies /1/. Then the requirements and first solutions for an innovative definition of NC-interface by making a connection between planning (CAP) and manufacturing (CAM) which is based on object-oriented structures are shown. Here it is basically irrelevant whether the NC-programming is done on the shop-floor or in the operations planning department. Object-oriented structures resulting during the IR programming follow, which correspond with analog views.

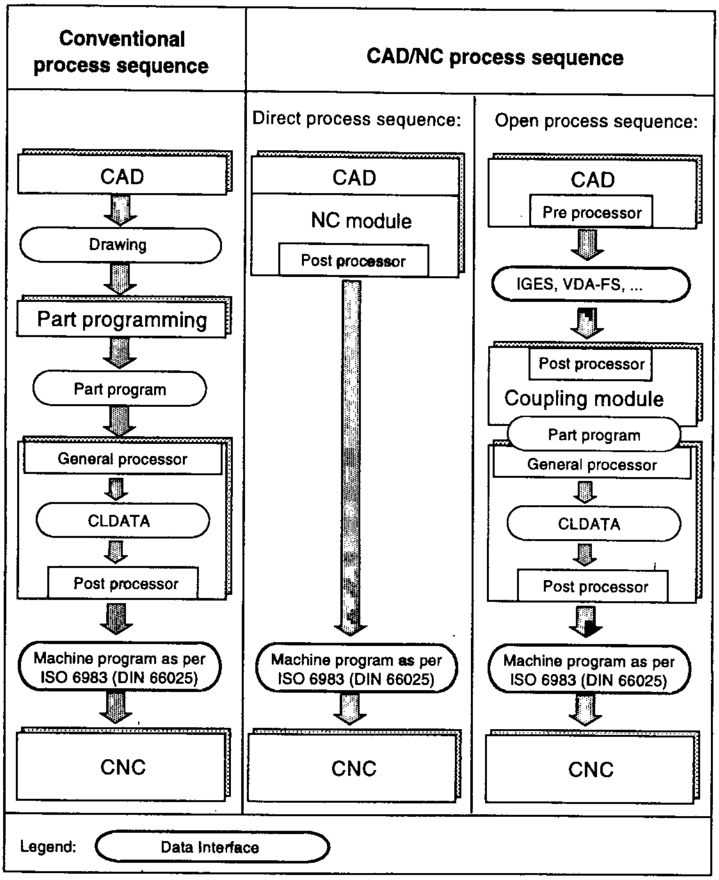

Fig. 1.1: Present CAD/NC process sequences

2 Present Deficiencies and Characteristics of the New "C++" Process Sequence

Present deficiencies of the DIN 66025 are:

- the extremely time consuming expenditure on testing and improving NC-programs on the machine because of insufficient information and a lack of transparency concerning the NC-programs;
- little possibility for the skilled worker to interfere in order to make modifications (i. e. for taking into account modified tools, modified mounting situations etc.);
- no backward documentation concerning optimizations of the machining process;
- inadequate transferability of NC-programs to different machines/control systems.

Derived from the deficiencies mentioned above, the essential requirements to a new NC-interface for conventional and open NC-machine controls are summarized in fig. 2.1. Especially important are:

- user-oriented supply of the information necessary for testing and optimizing programs on the machine;
- ensuring of the skilled worker's empirical knowledge by bi-directional information processing;

- use of the worker's know-how and increase of motivation by providing secure possibilities of user interaction.

According to the requirements as shown in fig. 2.1 a prototype of the new process sequence was developed. For this purpose design features and machining objects were defined as can be seen in fig. 2.2, which are connected by different types of relations. An object combines data concerning a partial area of the workpiece in a logical unit using a semantic component /2/.
For example, the workpiece model created by the technical designer is composed of several design features like the seat of a roller bearing, ribs or coolant drill-holes. These components determine and ensure as a whole the functioning of the workpiece. In order to guarantee this functionality quality-describing attributes are assigned to the design features. Consequently, a considerably higher level of information is achieved than in the former geometry-oriented interfaces like IGES or VDAFS (fig. 1.1).

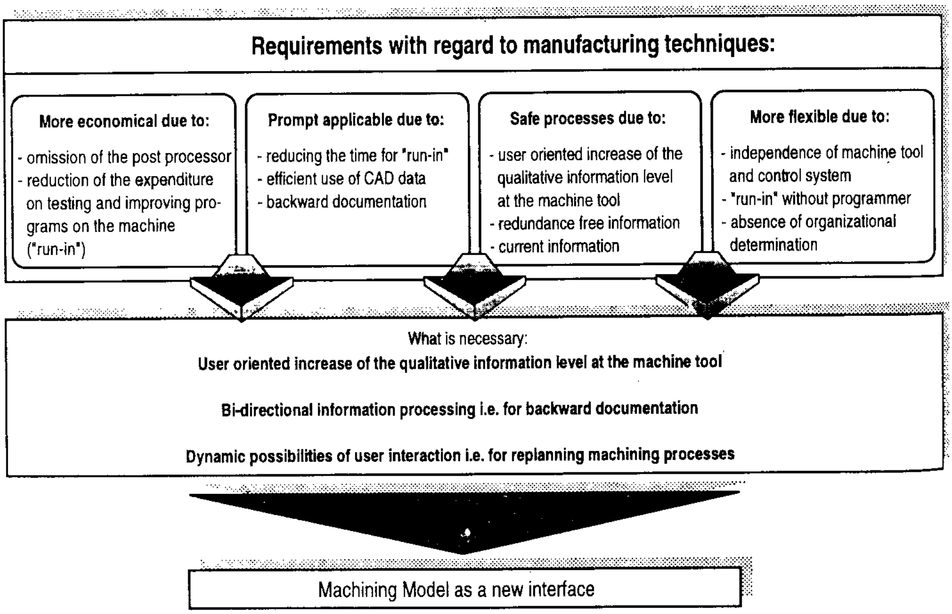

Fig. 2.1: Requirements on a new NC-interface with regard to manufacturing techniques

The design features generated during the design process do not contain any methods for defining the machining process. Therefore, they are converted into machining objects during the analysis and completion of the design features as is indicated in fig. 2.2.

If design features from CAD should not be available, then the machining objects have to be defined manually by identifying the machining tasks based on the design data. This can be done by using the CAD geometry or conventional technical drawings.

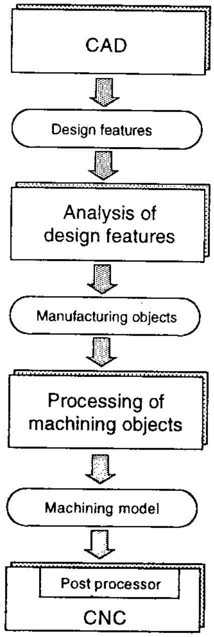

Fig. 2.2: New Process Sequence

The machining objects (MO) are the basis of the machining model. Its structure and processing in the numerical control system will be further explained in the following chapter. Because the machining of a surface can be normally done by using different technologies, a new solution was found. So-called macro and elementary machining objects are defined for describing the machining tasks and assigning of the machining technology /3/.
The macro machining objects (MMO) correspond to the description of the machining task and represent a higher form of organization as compared to the elementary machining objects. As a rule, several elementary machining objects (EMO) are derived from one MMO to represent the partial machining tasks such as "centre drill", "rough bore" etc.

3 Structure and Integration of the Machining Model into the New NC Process Sequence

Considering the mentioned requirements a machining model results which is structured as shown in fig. 3.1. As can be seen here, the machining model is subdivided in partial machining models. This subdivision is necessary to consider that a workpiece is often manufactured in more than one mounting situation.
A machining object consists of attributes and methods as for example methods used for determining the tools. From these methods, which are connected with the machining objects, object-oriented computerized machining instructions for the tool machine result. These instructions are transformed by post processor functionalities, which are integrated in the respective CNC, either directly into standard values for the individual axes and switching commands or, as a migrational concept, into conventionally machinable NC-instructions as per DIN 66025.

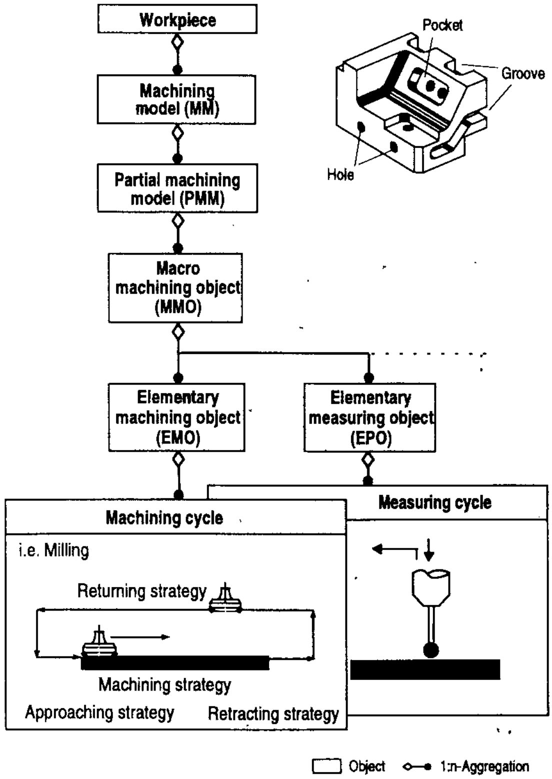

Fig. 3.1: Structure of the machining model

By the demonstrated subdivision into different interconnected machining object classes as well as by their window and pictograph oriented form of representation a user-oriented support of the skilled workers and their actions is ensured. At the same time with each object the information is deposited as to how it was derived and to which degree changes can be made without any risks involved. Such the required bidirectionality is guaranteed as well as the conditions are created for situation-oriented modifications shortly before manufacturing is started, as for example the changing of a tool. On the right side of fig. 3.1 the so-called elementary measuring objects (EPO) are listed. They define measuring cycles with regard to measure workpieces on coordinate measuring machines (CMM). This is possible because macro machining objects have access to quality describing data like geometrical tolerances of form, position, orientation etc.

4 Application Examples

For the realization of the new machining model two aspects push themselves to the forefront:

- integration of the workpiece graphics in order to make a connection between the abstract machining model and the real workpiece,
- the application of a window-oriented interface for data input and output.

An important aspect regarding concepts for the future programming of numerically controlled machine tools is the preparation and availability of machining data in a way that corresponds with the proceedings of skilled workers and their logical thinking and acting. It is therefore necessary to turn away from purely textual machining instructions and to turn to graphically interactive operation. The machining model consisting of machining objects offers here the opportunity to structure data according to the future requirements.

Handling of the Machining Model

Because a multitude of data levels would confront the skilled workers with a very confusing system, the machining objects are presented in two levels. In fig. 4.1 the information levels of a machining object are shown. Starting out from the first level "machining object" the information content is specified according to geometry, technology, tool and machining program.

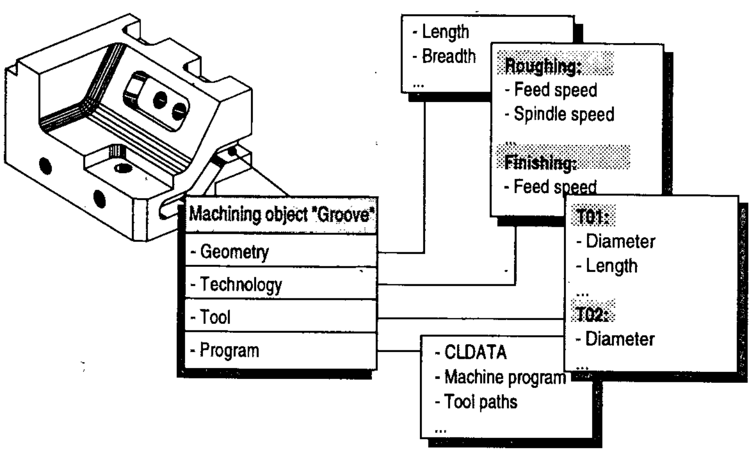

Fig. 4.1: Information structure of the machining model

The graphical interactive aspect of generating a machining object can be explained with a simple example. The geometry of a groove is defined either by using a contour (fig. 4.2) or by entering the parameters (fig. 4.1).

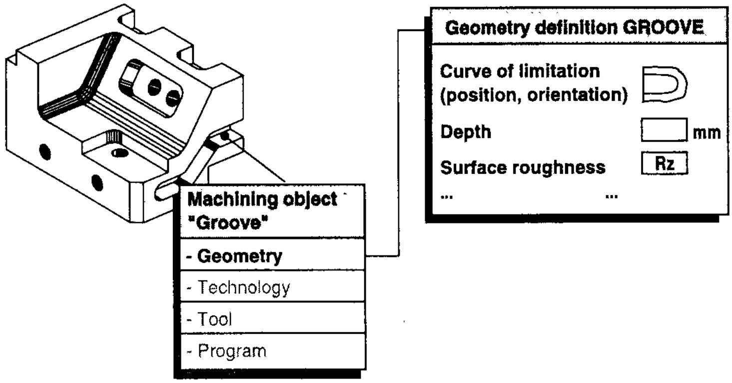

Fig. 4.2: Geometry definition of a machining object

As a next step within the definition of the machining object the technology and the tool have to be determined (fig. 4.3). In order to support the skilled worker in the selection of the machining strategy and the necessary tool a connection to a tool and technology data base is conceivable.

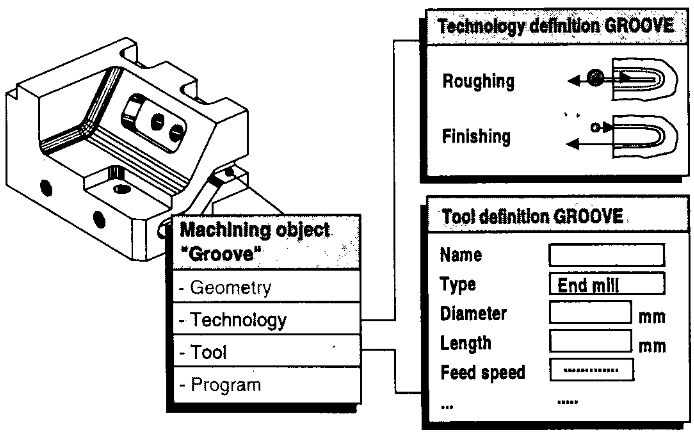

Fig. 4.3 Technology definition of a machining object

Data Interchange Format of the Machining Model

Using conventional interface formats as, for example, IGES or VDAFS (fig. 1.1) often results in a loss of information. In the generation of part programs with machining-oriented NC-programming languages the programming is often done in relation to the workpiece geometry. Transfering them according to DIN 66025 results in the machining instructions purely, without showing such a relation. This means that a backward connection between NC-program and part program in case of modifications on the shopfloor cannot be made so easily. This deficit has to be removed with future interface developments.

The Institute of Control Technology for Machine Tools and Manufacturing Units (ISW) intends to use this object-oriented machining model as a basis for future data exchange. This means: no loss of information during the transfer between different interface formats, because the machining model is always exchanged and so it is available all the time and at every point in the process sequence. Furthermore, a bidirectional data exchange between the manufacturing department and the other departments is possible.

With STEP there is a broad basis for the development of such a machining model. To be able to integrate further developments concerning STEP into the machining model, the corresponding tools like the modelling language EXPRESS as well as the necessary implementation methods in the area of data access und data exchange are applied. Fig. 4.4 shows the data interchange using the STEP format.

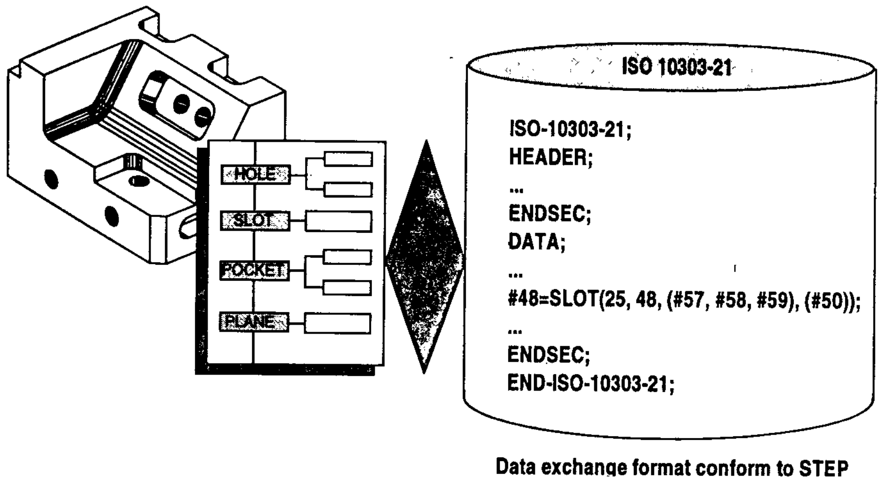

Fig. 4.4: Data interchange format of the machining model

Realization of the machining object-oriented interface

An additional deficit of conventional interfaces is, as was mentioned in the beginning, the lacking exchangeability of NC-programs between different controls resp. machines. The object-oriented structure of the machining model has the advantage that it can be adapted easily to changes occuring during the generation of the NC-program (e.g. in regard to the used tools or machines). In order to present the importance of this aspect of a uniform object-oriented machining model for the practice, the machining object-oriented interface is implemented on different machining platforms available at the ISW. Fig. 4.5 shows the interface based on machining objects as a sum of the results gained so far from the Projects WesUF (action-oriented solutions for machine tool controls in support of experienced and team-oriented work) and WNF (shop-oriented user support for sculptured surfaces).

Alternative Machining Models

Present NC-programs cannot be machined on a machine tool with different kinematic requirements in case of a breakdown, unless extensive adaptions are made. The object-oriented programming method allows during the generation of the machining model to assemble earlier defined machining objects according to the new kinematics without major expense. In fig. 4.6 we have two examples, a part of the machining program for a 3-axes machine and the modificated program for a 4-axes machine.

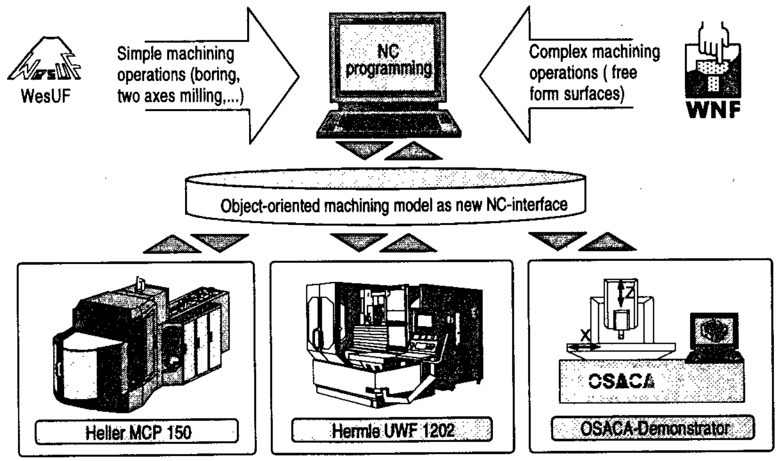

Fig. 4.5: Realisation on different machine tools and controls

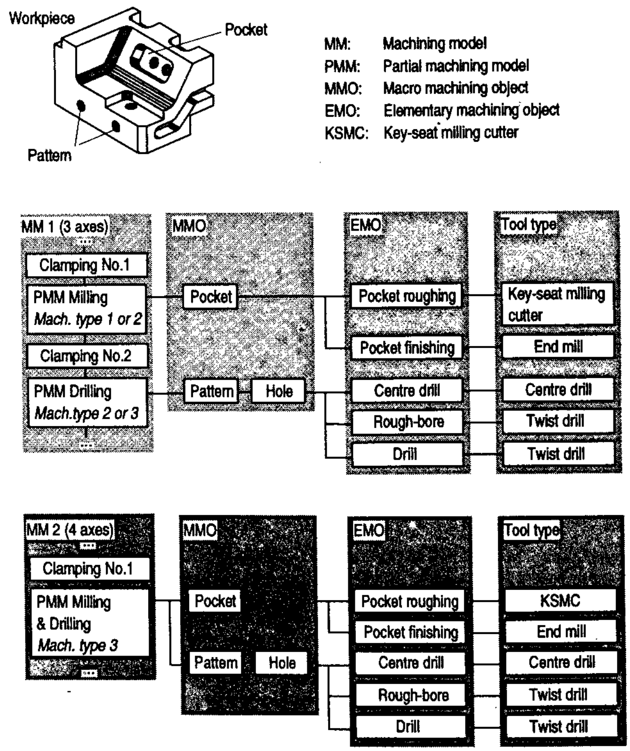

Fig. 4.6: Alternative machining models

Manufacturing Objects for the Machining of Sculptured Surfaces

The new process sequence seen in fig. 2.2 can not only be used for 2 1/2-axes drilling and milling machining but also to the same extent for 3..5 axes machining of sculptured surfaces. Fig. 4.7 illustrates, how multi-axes machining of sculptured surfaces is described by machining objects. However, for the process of NC-programming it is necessary to replace presently used strategies like linear machining of the entire workpiece by object (or geometry)-oriented strategies. The analysis of the design features provides as a result macro machining objects which represent geometry-oriented individual machining of specific workpiece areas (e.g. pocket, groove, ...). These macro machining objects are related to strategies, which ensure a technologically useful and time optimal machining. In addition, such a classification makes it easier to compute the tool approach and collision free course, which is usually very time consuming. Especially in the case of 4- and 5-axes machining advantages in regard to collision-free computation of machining instructions are to be expected.

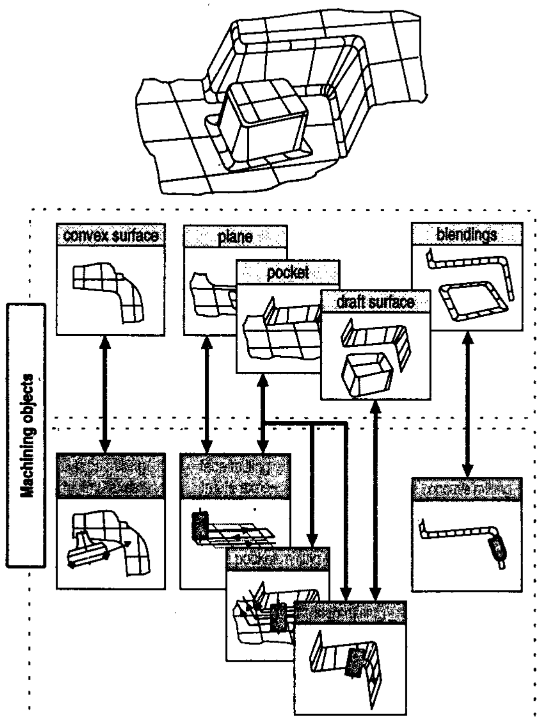

Fig. 4.7: Examples for multi-axis machining of sculptured surfaces based on machining objects

5 Object-oriented solutions with RC-programming

When programming industrial robots various techniques are used: direct, indirect and hybrid. Direct method are 'teach in' and 'play back'. Indirect methods are separated in implicit and explicit method (fig. 5.1). An often used explicit programming method is based on the industrial robot language (IRL, DIN 66312). Programs generated with IRL are textual and elements of higher programming languages (e.g. PASCAL) are used. A critical evaluation should determine wether a PASCAL-oriented structuring is necessary or not. It has to examined how user- and shop-oriented the IRL language actually is. Graphical support and further use of generated CAD data are additional requirements in order to remove similar deficits like the ones that occured with the NC-programming.

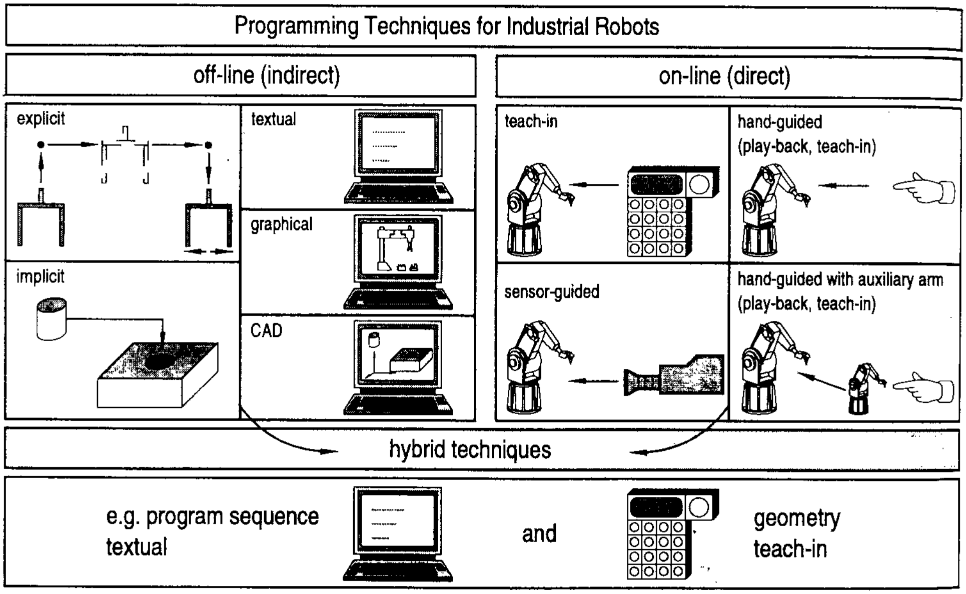

Fig. 5.1: Programming techniques for industrial robots

The object-oriented modelling of the tasks to be performed by industrial robots can be one solution here. Objects used for IR programming have to be technology-oriented. Fig. 5.2 shows technology-oriented classes for assembly objects.

The following fig. 5.3 shows the concept of the IR programming system with different levels of abstraction. Classes and objects are defined for each robot action which correspond with the instruction format of common textual robot programming languages. Based on this, application-specific classes and objects (fig. 5.2) for complex movements in special applications (e.g. assembly) are declared. On a higher level workpiece-oriented classes and objects can be generated, for example, for modelling complete assembly process plans. By these three levels which build upon each other, continuity from explicit to implicit robot programming is achieved.

Elements of the lowest explicit level are available anytime, so that the full flexibility of the robot control can be exploited. The extensibility of the system for special usage on an application-specific level is easily done.

For a user-oriented access the class structure is coupled with a graphic system (e.g. MS-Windows). The classes include method declarations which allow a specification of the object attributes by simple dialogues. Further should be possible to select the individual objects and to assign them to a process sequence graph. For this a graphical representation of the classes and objects as icons can be recommended.

As with programming with machining objects, objects should be processible directly at the control without conversion in a data interface. This is seen in the bottom part of fig. 5.3.

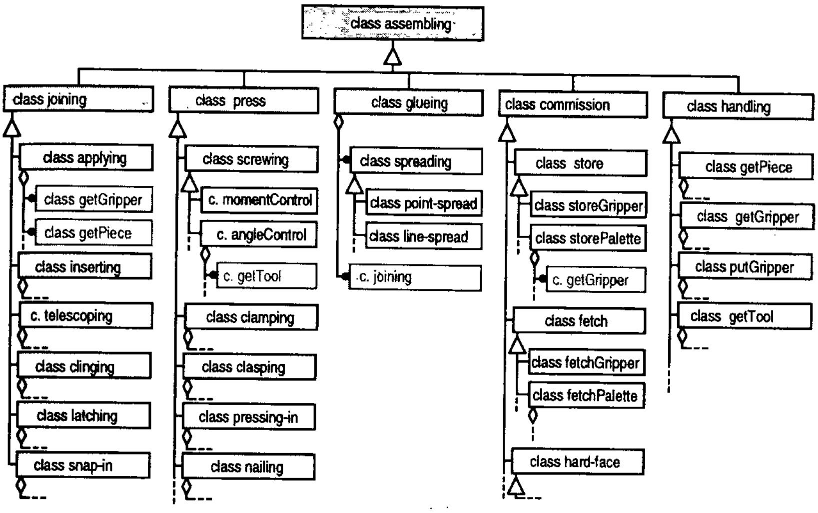

Fig. 5.2: Class-structure for programming of assembly tasks

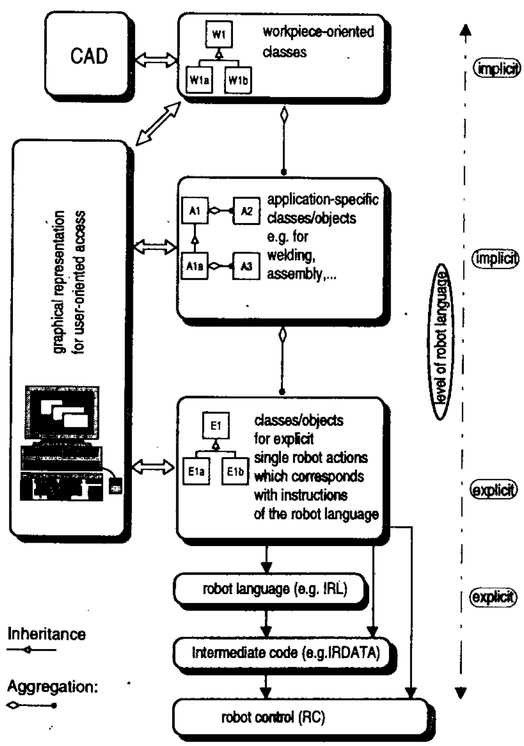

Fig. 5.3: Object-oriented robot programming

6 Summary

With the demonstrated solution the areas CAP and CAM are connected bi-directionally through a machining model which is based on object-oriented structures. Therefore, the presently existing gap between the operations planning department and shop floor is closed. The comprehensive application of the objects contained in the machining or assembly model provides the user at the machine tool or at the industrial robot with highly informative machining and control data in a user-oriented way, so that the testing, modifying and optimizing of machining and assembly tasks become faster and more secure. Additionally, the experience and know-how of the skilled worker are now available to the planning department. Based on the parameterization connected to the objects the generation of variants and the reusability of solutions for individual machining or assembly tasks is improved considerably.
It is our goal for the future, to use the machining model as programming and NC-interface continuously in the process sequence and at the control system. As migration concept it is planned to continue by means of machining objects with the generation of conventionally machinable NC-sets according to DIN 66025 or IRDATA in order to use the presently applied NC control systems without having to make technical modifications.

7 References

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