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HIGHER EFFECTIVENESS IN THE CREATION AND APPLICABILITY OF CAD SOFTWARE

Abstract. Development costs of CAD software, which is created solely in teams of highly qualified experts, raise growing pressure on the effectiveness of its creation and applicability. The present contribution summarizes the basic principles of a concept extending the hitherto methods of software creation by a substantial increase in repeated application of problems already worked out. Practical experience with the application of both the traditional and newly proposed methods show high effectiveness as well as good prospects for applications in a broad range both of CAD problems and of solvers, even under conditions of non-uniform hardware and basic software.

1. Problem formulation

The object function of CAD software may be formulated as acceleration and improvement in the design of technological work and the creation of a corresponding primary data base for the follow-up pre-production and production stages.

In order to ensure effectiveness of their development and applicability the individual CAD systems should also have a number of partial, partly even contradicting, properties [1]:

- ease of application,
- wide range of applications,
- separate applicability of programme modules,
- ease of extension,
- ease of modification,
- feasibility of implementation.

It is obvious that all these requirements can be met complexly only by extensive programme packages implemented on very good hardware. The required objective, however, is an effective creation and applicability of even simpler programme packages and/or separate programmes which will meet, at least partly, the above mentioned requirements.

Since the majority of the present CAD software is of turnkey character, only the first two properties can bring benefit to the user. With regard to the generally known disadvantages this software following from its too large universality, the three-layer philosophy for the desing of CAD software [2] is being proposed as a progressive trend so directed that also the user can utilize the remaining properties that have, so far, been beneficial mostly to the software designers only.

2. State-of-the-art

Let us make first a brief recapitulation ot the current methodology of software design that is the basis of the proposed solution method.

The basic design principle of every good programme package is the modular structure in which the individual modules perform the necessary elementary operations. Every such programme module (PM) may be defined [3] as a "closed system of rules and parameters aimed at solving a certain problem, the contents and function of which are, within the programme, so firmly determined that no redundancy originates, that it can not shrink further, and that a simple combination with other PMs is made possible".

It is also desirable that the individual PMs have an immovable, unambiguous and complete interface defined toward the programme, and as flexible an interface toward the computer as possible:

- the requirement of immobility of the interface toward the programme, even though trivial at first, means that any supposed changes within a PM may cause, at most, a change in the width of the interface but not its shift,
- the requirement of unambiguity of the interface toward the programme means that it is a simple one and easily describable (word description, listing),
- the requirement of completeness of the interface toward the programme means that everything the programme needs from a PM can be obtained through this interface,
- the requirement of flexibility of the interface toward the computer means the possibility of a simple adjustment to inevitable changes, e.g. by concentrating all places of immediate contact with the computer into specialized subroutines having an exclusive right of communication.

For an effective PM desing a number of generally known ways is valid. Among the most important ones there belongs the application of:

- problem orientated languages,
- structured programming,
- standard subroutines.

It is obvious that further substantial benefits may be brought about especially by repeated application of already worked out problems. Even in a consistent modular programme structure, this is usually hindered by a number of circumstances.

One of the principal problems is the inconsistance existing between the extensive, and therefore also repeatable use, and the simple applicability. The more extensively used a certain problem is (e.g. a mathematical problem in comparison with the problem of a structural member), the more difficult it is for it to be applied in current desing practice and vice versa. A good CAD software, however, must possess the most concrete information representation on the designed products in order to be simply applicable by designers who are not and even cannot be experts in all the problems to be solved on the product by means of a computer.

From the above definitions it follows that even in identically orientated PMs both the scope and the interface depend, in most cases, on the particular CAD software they are part of. Since, however, the desired aim is an effective creation and applicability of programme packages of various scopes and levels, it is practically impossible to regard the existing programmes as an available source of worked out problems, disregarding the difficulties in organizing such an approach, in implementing it on a particular computer, in the documentation manner, etc.

3. Proposed solution

The above mentioned considerations have led to the idea of creating a library, independent of CAD software that would contain only parts of programmes for suitable defined complexes of operations [4]. In order to distinguish them from the classical PMs, including also elementary operations, we shall call these parts of programmes the modular sections (MS) and we shall, henceforth, regard them as the basic building blocks of CAD software.

When applied to a particular programme, these MSs fulfil the function of complex programme modules and all the above mentioned definitions, requirements, and design rules must hold for them and their interfaces.

In consideration of the analyses performed, a three-level hierarchy model has been adopted for the library of these MSs (MSL). As identification symbols, the subject and objective of solution have been chosen at all the levels. Then the abstractness (concreteness or universality) specialty of these basic identification symbols is an auxilliary criterion. This consistent approach at all the three levels of MSL leads to a simple, lucid and analoguous matrix structure.

The basic inconsistency between the required particularity of the information representation of the final CAD software and a wide applicability of already worked out problems is solved by internally sectionalizing the MSs into MSs with differentiated degrees of abstractness of the solved problems. Thus, the first level of the MSL is sectionalized into four blocks:

- mathematical-logical block (MATH-LOG) is contained in the MSs with the highest degree of universal applicability. Their common characteristic is the mathematical-logical information representation of the problems solved. These MSs should be standard part of essential software immplementation on every computer. Included are especially solutions of mathematical problems, operations with data files, control and checks of programme system runs, basic graphical software, dummy input and output routines, etc. With regard to the high degree of applicability of the MSs of this block, their outstanding merit is the high effectiveness of their creation. On the other hand, the disadvantage is the rather difficult immediate applicability in CAD software, which is brought about by the high degree of abstractness of the problems solved.
- physical-mathematical block (PHYS-MATH) contains MSs with a medium degree of applicability. Their common characteristic is the physical-mathematical information representation of the solved problems whose solution should be performed to the maximum degree by the MSs of the mathematical-logical block. Also included is the MS for the solution of static characteristics, stress, deformations, etc. in the physical-mathematical models in technological environment such as bars, beams, plates, etc. In view of a lower applicability and a higher degree of concreteness, the MSs of this block represent a partial compromise between effectiveness of their development and simplicity of their immediate applicability in CAD software.
- structural-physical block (STR-PHYS) contains MSs with a low degree of universal applicability. Their common characteristic is the structural-physical information representation of the problems solved. To increase the creation effectiveness of these relatively specialized MSs it is necessary during their creation to employ MSs of the preceding two blocks as much as possible. It is also advisable to employ classes of design solution, as well as the solution scopes of the individual MSs as wide as possible.

  Computer aided desing of active parts of designed components and their assemblies, e.g. gearing, grooving, press-on joints, etc. is an example of such a problem solution. The disadvantage of lower applicability of the MSs of this block is counterbalanced by considerable simplicity of their immediate applicability in CAD software.

- product-structural block (PRO-STR) contains MSs with the lowest degree of universal applicability. Their common characteristic is the product-structural information representation of the problems solved. Computer aided design of parts and their assembly groups is an example of such MSs. In view of the high specialty of the MSs of this block it is necessary to pay regard to effectiveness during their construction. This will be done best by using the MSs of the three preceding blocks and as wide a scope of the solved class of problems as possible. The main advantage, however, is the direct applicability in CAD software due to the highest degree of concreteness of the information representation of the solved problems and, therefor , with the best applicability prospects for practical design.

In an introduced MSL system, the arrangement of the individual blocks in dependence of their abstractness/concreteness of their subjects and objectives of solution is shown schematically in Fig. 1.

The medium level of MSL makes provisions for the individual blocks to be sectionalized into particular classes of problems. Outer as well as inner sectionalizing of technological fields according to the International Decimal Classification [5] and the mathematical models currently employed in these fields are used as the basis for defining also the rank of the subjects and objectives of solutions in the individual MS classes. With regard to the great number of problems solved in CAD software, it is advantageous that the matrices of the individual blocks may be partially incomplete and that, as need may be, can be gradually supplemented and refined.

During the construction of an MS, is advantageous to use not only the MSs of the more abstract blocks but also those of the same block. For instance, during the construction of the MS for the calculation of forces in the shaft support in a gear box, it is advantageous to employ the MSs for solving the forces in a gearing, etc.

In the introduced MSL system, tho arrangement of the various classes in dependence on universality/specialty of their subjects and objectives of solution is shown schematically inside the various blocks in Fig. 1.

The third level of the MSL solves the requirements of different scopes and levels of solution of MSs within the same class of problesm for the implementation in various CAD software systems. Each class of the MSL can, therefore, contain more MSs that solve the problem in hand at a different qualitative and quantitative level.

During the construction of new MSs, it is advantageous to use both worked out MSs of the more abstract blocks or other classes of the same block and the MSs of the same block, especially during the gradual creation of the more extensive MSs and for higher solution levels.

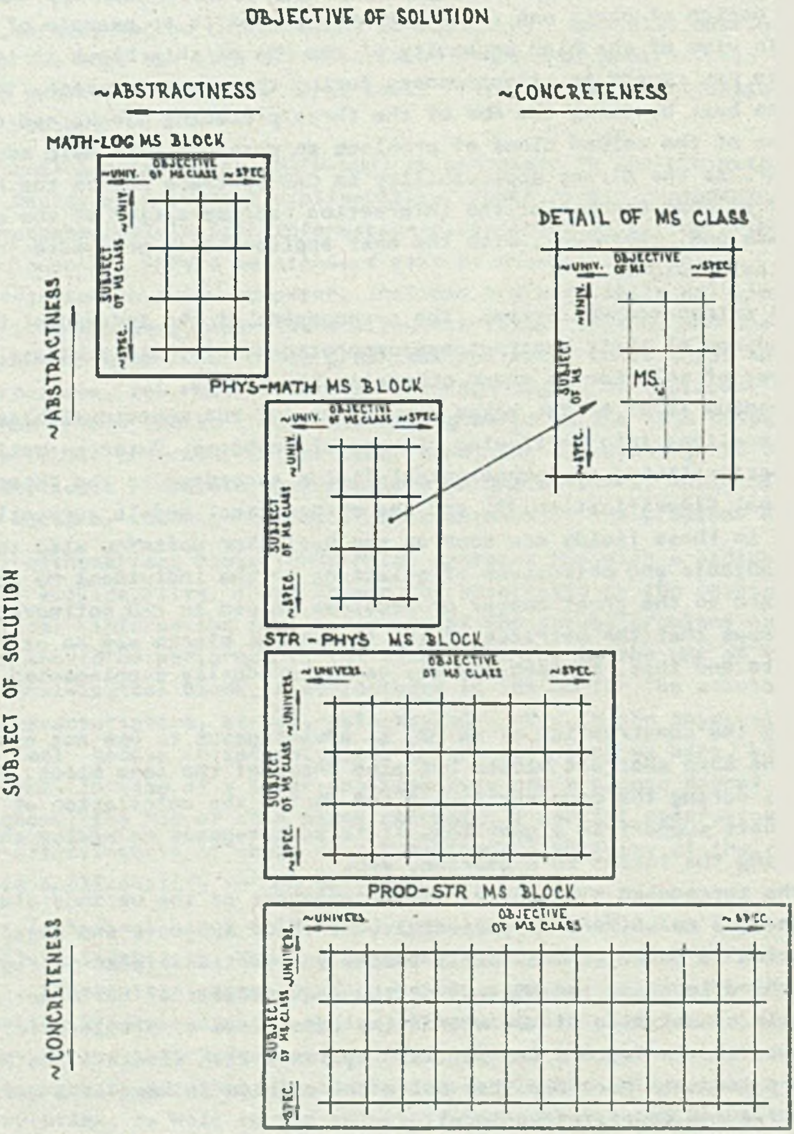
OBJECTIVE OF SOLUTION
~ABSTRACTNESS
~CONCRETENESS
MATH-LOG MS BLOCK
PHYS-MATH MS BLOCK
STR - PHYS MS BLOCK
PROD-STR MS BLOCK
DETAIL OF MS CLASS
MS
SUBJECT OF SOLUTION
~ABSTRACTNESS
~CONCRETENESS
OBJECTIVE OF MS CLASS
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Fig. 1

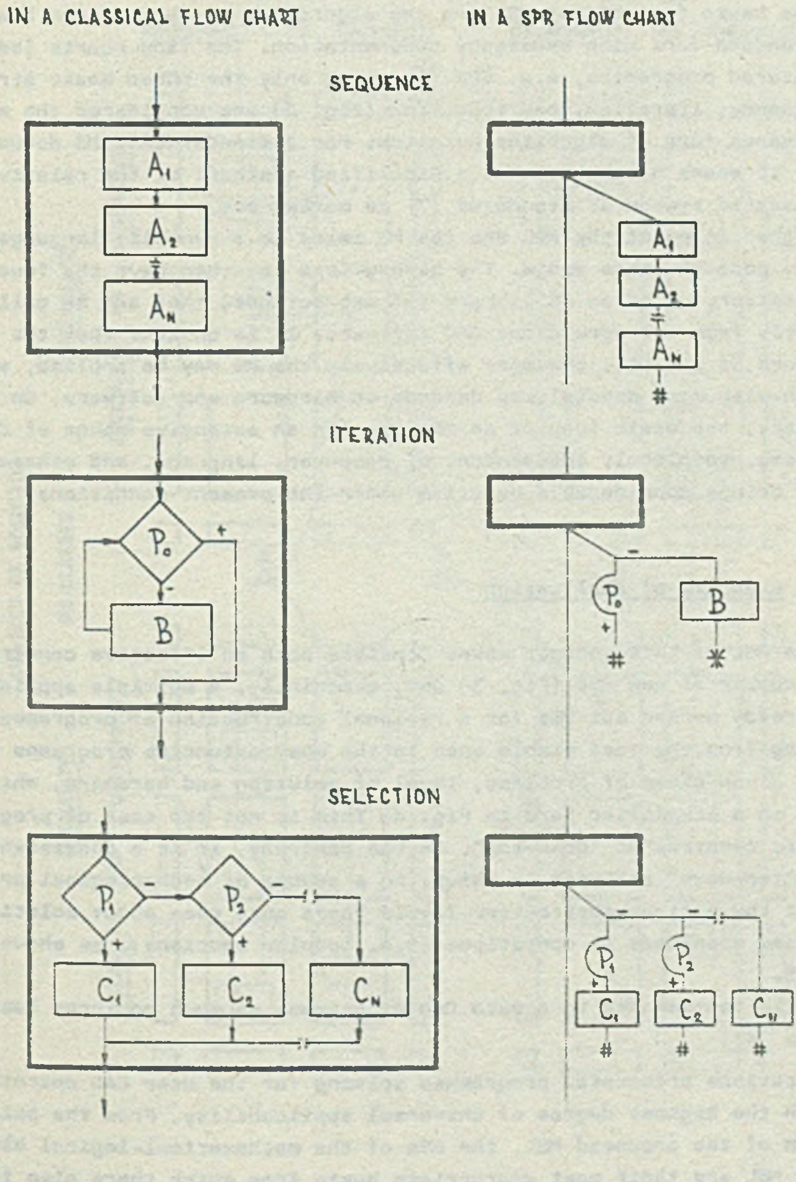
IN A CLASSICAL FLOW CHART
IN A SPR FLOW CHART
SEQUENCE
A1
A2
AN
ITERATION
P0
B
SELECTION
P1
P2
C1
C2
CN

Fig. 2

The arrangement of particular MSs in an introduced MSL system in dependence on universality/specialty of their subjects or objectives of solution is shown in Fig. 1. Here, it also holds that the matrices of the various classes may be partially incomplete, that, according to need, they are expandable or supplementable, or when a large number of MSs has been reached, they can be subdivided into two or more new classes.

The basic form of the MSL are the algorithms of the various MSs written in standard form with necessary documentation. The flow charts leading to structured programmes, e.g. SPR [6] using only the three basic structures - sequence, iteration, and selection (Fig. 2) are considered the most advantageous form of algorithm notation. For a standardized MS documentation, it seems necessary that a simplified abstract of the relatively complicated system of standards [7] be worked out.

Higher forms of the MSL are the MS texts in a symbolic language or in binary code on store media. The binary form may then have the function of a repository or of an MS library (of subroutines) that can be called directly from the worked out CAD software. It is obvious that the higher the form of the MSL, the more effectively the MS may be applied, even though with more specialized demands on hardware and software. On the contrary, the basic form of an MSL is, for an extensive range of CAD problems, completely independent of computer, language, and otherwise, which brings considerable benefits under the present conditions.

4. Examples of application

The MSL of this concept makes possible both an effective construction of a number of new MSs (Fig. 3) and, especially, a multiple application of already worked out MSs for a rational construction of programmes ranging from the most simple ones to the most extensive programme system for a given class of problems, level of solution and hardware, which is shown in a simplified form in Fig. 4. This is not the case of programme systems constructed "down-top". On the contrary, it is a consistent use of a "top-down" analysis in which, in a number of technological problems and at the various abstraction levels there must come about solutions of the same complexes of operations (i.e. modular sections), as shown in Fig. 5.

It is recommended to create CAD programmes as such on three basic levels [4]:

- operations orientated programmes solving for the user CAD operations with the highest degree of universal applicability. From the point of view of the proposed MSL, the MSs of the mathematical-logical block of the MSL are their most appropriate basis from which there also follow analogical points of view on the development effectiveness and applicability of these systems.

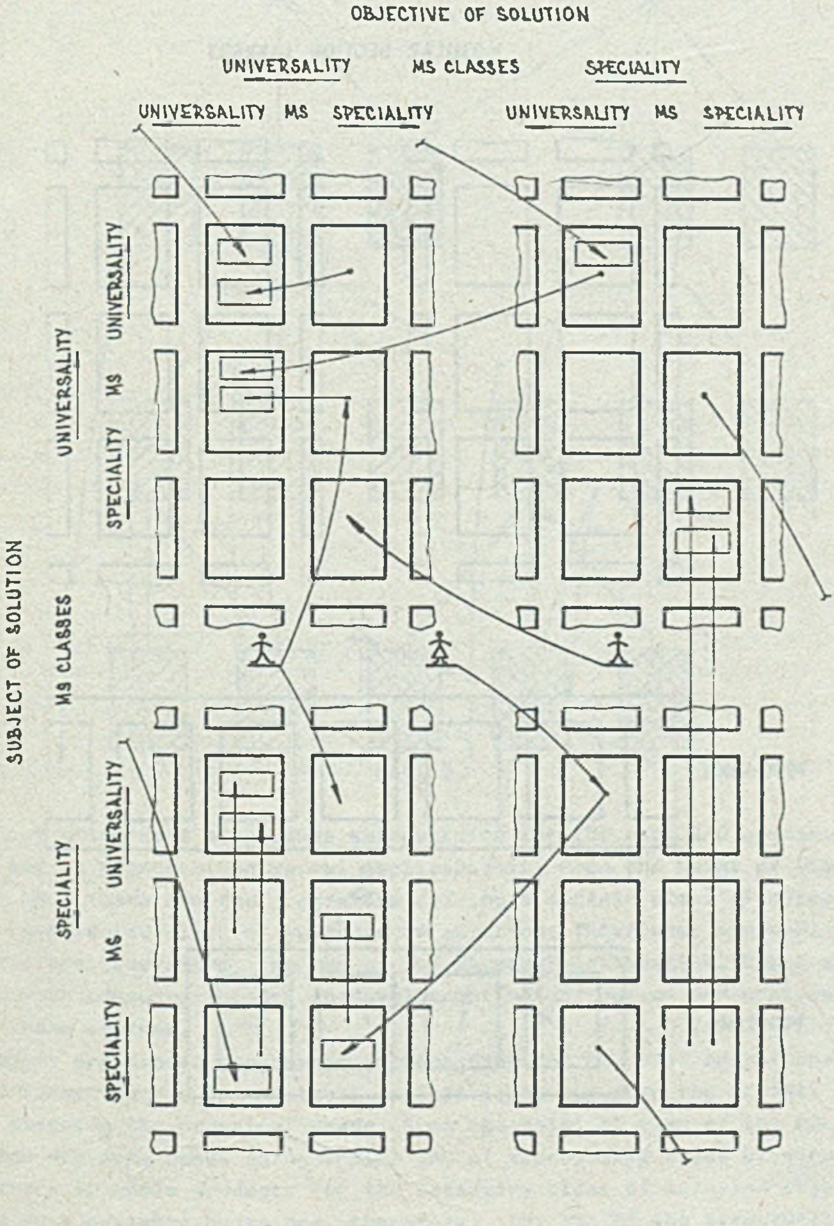
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Fig. 3

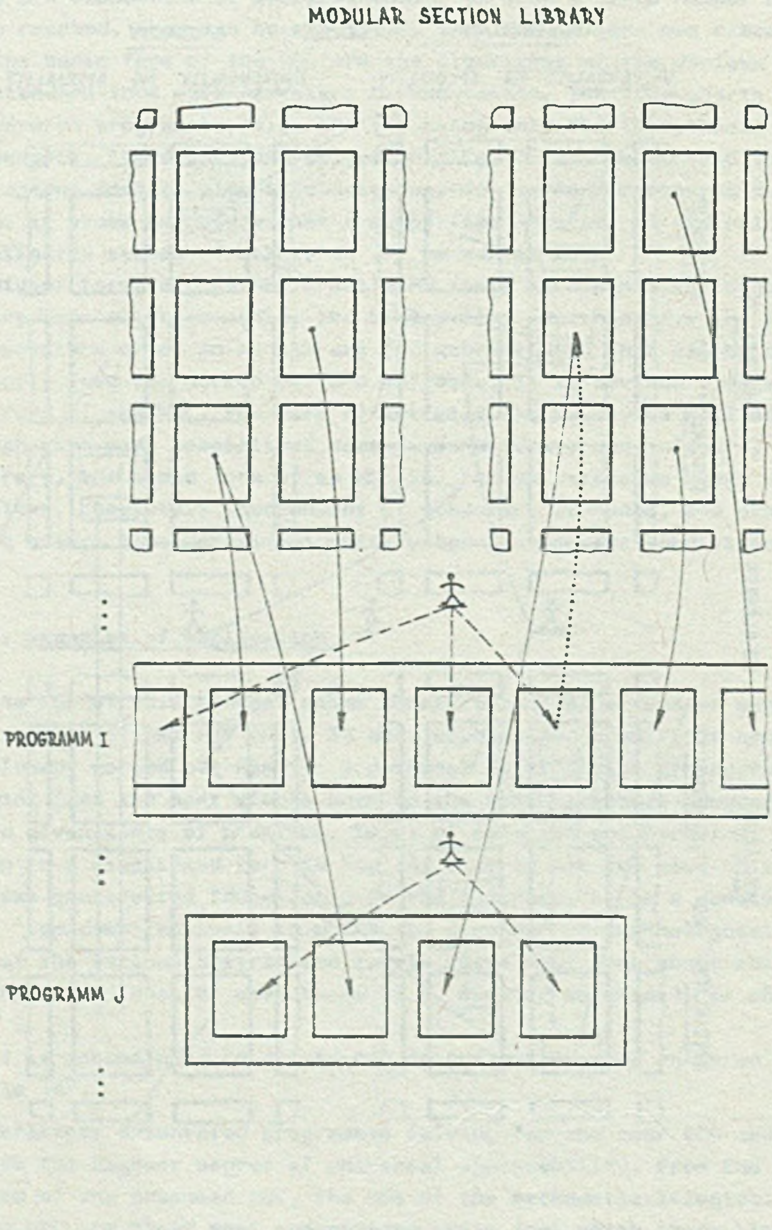

Fig. 4

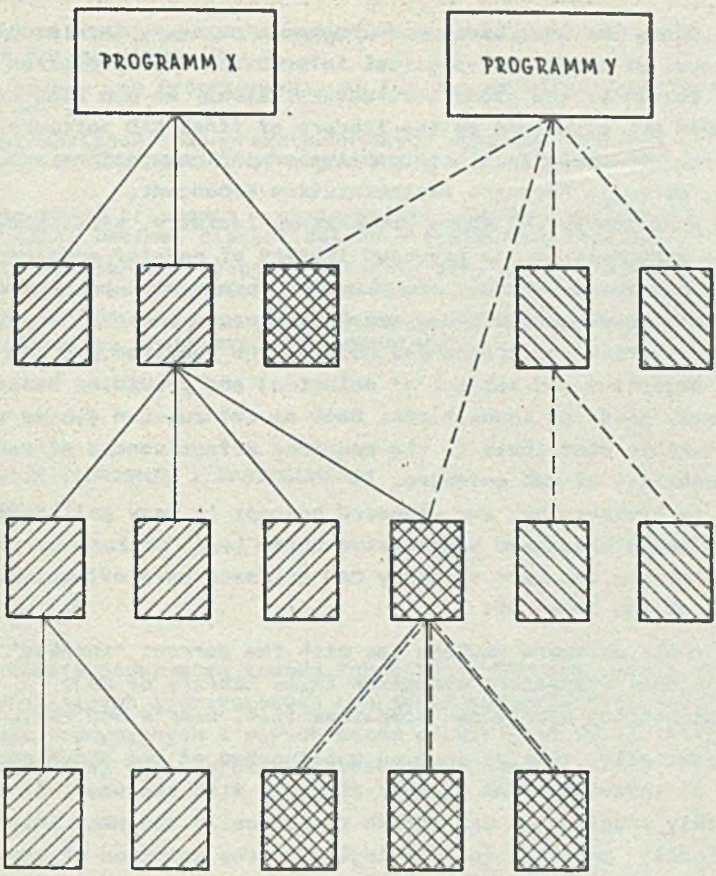

Fig. 5

- object orientated programmes safeguarding for the user CAD operations of medium degree of universal applicability. From the point of view of the MSL, these are the programmes solving a certain class of objectives for a selected class of subjects of solution. Their most appropriate basis are, therefore, the MSs of the physical-mathematical block of the MSL with adequate results in development effectiveness and applicability of these systems,
- subject orientated programmes safeguarding for the user operations with the lowest degree of universal applicability but with the highest degree of matching the practical needs. From the point of view of the MSL, these are programmes safeguarding CAD of appropriate class of structural members or whole products for the necessary class of solution objectives. The most suitable basis are, therefore, the MSs of the structural-physical and product-structural blocks of the MSL, while for the development and applicability of these systems the same rules must hold.

Dividing the last mentioned programme category into problems solved at the level of structural-physical information representation and into problems solved at the product-structural level, we can also apply the proposed MSL structure to the library of final CAD software. Due to hardware non-uniformity, its particular implementations are, for the time being, strongly hardware implementation dependant.

In addition to the above properties, lucidity, simplicity and sameness of the structure of the proposed library of modular sections, as well as of CAD programme systems, also create appropriate prerequisites for the construction of a relatively simple automated information system seeking modular sections or programmes solving the required problem (i.e. operation, objective and subject of solution) and providing basic information currently given on index cards. Such an information system would also considerably contribute to the required effectiveness of construction and applicability of CAD software.

It is obvious that the proposed concept is very well applicable even to the above mentioned progressive three level philosophy for CAD systems [2], enabling the user to apply CAD software more effectively and flexibly, namely at the level of:

- the whole software package (as with the current "turnkey" CAD software),
- individual operations complexes (i.e. library of MS),
- supplementing user's own complexes (i.e. user's own MSs).

Essentially, this is just an application of the above concept at a level of individual CAD systems directly with the user. At the some time, the newly created MSs may enrich reciprocally the MSL, into which it is principally possible to file logically the solution of many technological problem of arbitrary extent, level of solution and form of processing.

5. Conclusion

By way of conclusion, it may be stated that the hitherto experience with the construction of CAD software in ŠKODA Plzeň, based on the above mentioned concept, show high effectiveness of work and indicate a prospective application even in a wider scope also under the conditions of non-uniform hardware and appropriate basic software.

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WYŻSZA EFEKTYWNOŚĆ W TWORZENIU I ZASTOSOWANIU OPROGRAMOWANIA CAD

S t r e s z c z e n i e

Praca ta podsumowuje podstawowe zasady konceptu wywodzącego się z metod dotychczas istniejących a dotyczących tworzenia oprogramowań. Doświadczenie w stosowaniu tradycyjnych i nowych metod wskazuje na wysoką efektywność jak i perspektywy dla szerokiego stosowania CAD.

БОЛЬШАЯ ЭФФЕКТИВНОСТЬ ОБРАЗОВАНИЯ И ПРИМЕНЕНИЯ ПРОГРАММИРОВАНИЯ CAD

Р е з ю м е

В этой работе подводятся итоги основного принципа концепций, происходящих из до сих пор существующих методов, а касающихся образования программирования. Опыты в применении традиционных и новых методов указывают на большую эффективность и перспективность широкого применения CAD.

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