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KNOWLEDGE BASE AND DIALOGUE IN CALCULATION CAD PROGRAMS FOR MECHANICS

Summary. This work presents an idea of construction of CAD calculation programs with the knowledge base realized by means of the frame technique. The structure of such a program is discussed. Chunks of knowledge from the application domain are characterized. The results are presented for calculations of helical assembly spring. New variants of design tasks are shown which may be solved through implementation of the knowledge base into the program. There is also given a description by means of frames of the selected elements of knowledge in the field of springs.

1. Introduction

The characteristic feature of CAD programs is their special conscientiousness to provide a user-friendly interface. As dialogue techniques menu and form filling are selected which allow to decrease the number of type-written errors, and minimize the time necessary to acquire the skill of using the program [3]. Computer graphics is used extensively and this makes it easier to evaluate the results of calculations fast. However, these efforts are not related with the types of design tasks solved with a computer, nor with its complexity. On the basis of analysis of the CAD programs which are known it can be said that they impose on the user a stiff procedure of solving tasks assumed by the programmer. This limits an engineer's invention, requires extra time for the preparation of a set of data demanded by the program. Traditionally, the following types of programs are distinguished: checking, searching, optimizing and the selecting from the catalogue. Their algorithms vary, but the general dialogue features and its shortcomings are common to them.
I. All the programs force the user to input data according to one scheme imposed by the authors of the program. For instance, it is impossible to give dimension proportions or geometric dimensions when calculating disc springs. It is similar

when calculating connection shaft - hub, the program demands the value of the torque and does not accept giving power and rotational speed. Oftentimes the program requires from the user many data which he does not always know (especially during calculation of shafts and gears). The default values are only rarely written into the program. A considerable part of these data recurs during iterations. Only in few programs (apart from the FEM programs) definitions of design tasks are stored. The authors do not know any program making it possible to transfer elements of a previously defined task into the current task. In the case of construction calculations there are no solutions known which make it possible for the program to modify, e. g. the used material or as in the case of connections shaft - hub the selection of a kind of connection by the program. The selection of the best connection would require from the user many iterations of the calculation for various connections many times giving similar data.

II. When analyzing the calculation process in the various programs we can say that there is no possibility of assuming different magnitudes as decision variables. The program changes only those magnitudes which have been selected by the programmer as decision variables. For instance, for helical springs the wire diameter and the number of coils are varied and then the length of the spring can not be the decision variable. The priorities for the constraints can not be defined either, i. e. it can not be indicated that certain constraints must absolutely be satisfied and the other ones can be violated to some extent.

III. Not all CAD programs store in disk files the results of calculations as dynamically generated catalogues. There are no programs at all which would automatically search these catalogues for the ready solution matching the user's task definition.

Getting rid off the shortcomings of the CAD programs requires a new development of their organization and of implementation methods. This paper presents the idea of construction of the CAD programs. It is postulated that these shortcomings do not occur in the software developed according to this concept. Next, the characteristics of the final software are enumerated. This is going to be achieved through embedding into the program the knowledge base on the application domain, calculation process and the program resources. In point 3. the idea of the CAD program with the knowledge base is given. Further on representation of knowledge about the application based on frame technique is discussed on the example of calculations of a helical spring assembly.

2. The suggested characteristics of CAD calculation programs

Evaluation of the features of the CAD programs given in the Introduction is the result of experiences with application programs implemented and with their use. Starting from this we can formulate the desirable features of CAD programs which should be satisfied in the final software, developed according to the concept discussed here, in the form of the following postulates.

I. The CAD program makes possible construction, optimization and checking calculations in one environment and this must be done in a definite order.

II. The program informs the user about the variants of construction of a technical object, about the calculation methods, design parameters and their domains. In addition, it ensures for the user making a selection among these possibilities, i. e. planning of the course of calculations.

III. In the design task the user may give either a single value or their sets. When a set is given the program calculates many times for values selected from this set. Such a possibility of varianting concerns the structure of object designed, the qualitative and quantitative parameters which describe it.

IV. A possibly wide set of constraints and a set of criteria are embedded in the program. The user selects constraints and possibly, the criteria which he would like to take into consideration in calculations.

V. At the user's order, the CAD program stores in disk files results of calculations. In this way the base (catalogue) of the generated solutions is created in case of construction and optimization calculations. The user may study this catalogue and formulate queries.

VI. The catalogue of the solutions is searched by the program for the ready solution of the new, submitted task.

VII. The user may take advantage of the previously defined task for modification and recalculation. He can also copy the selected elements of the definition for a new task.

3. An idea of a calculation program with knowledge base

The features of CAD programs quoted in the previous point are going to be achieved through embedding the knowledge base into the program. The authors of this work decided to represent knowledge by means of frames [2]. Being aware of great work expenditure required in implementation of the knowledge base the authors tried to distinguish the universal elements of the software when developing the idea of the program. They might be used in many programs for various applications. In Fig. 1. is presented the proposed structure of the CAD program with the knowledge base. Elements peculiar to application are separated by means of the vertical dotted line from the universal ones. The knowledge base contains definitions of domains (i. e. classes) of frames. They present schemes according to which information utilized by the user, in calculations and in management of the program performance may be stored. For every domain during the execution of the program, instances of frames, that is sets of specific information, may be created and stored in the base. In further part of this work we will always use the concept "domain" having in mind definition of the class of frames (this corresponds to the concept of "prototype frame" which is also used). The set of specific information stored according to the scheme described in the definition of a domain will be called "an instance of the frame" or only "a frame". By analogy to the terminology used in object programming we will speak of "the frame attribute" meaning "slot of the frame".

Among domains of frames defined in the knowledge base there are domains (as can be seen in Fig. 1.) which describe: (1) the object being calculated, (2) its mathematical model taking account of different calculation methods, (3) constraints, (4) global and partial criteria, (5) calculation procedures. To each of the domains may be attached actions which are procedural representation of certain knowledge. The domains which describe the object being calculated and actions connected with them must be written into the program by an expert from the very beginning for every application. Definitions of the domains of constraints, criteria, mathematical model, calculations procedures are universal. However, generating of their instances is based on expert's information. These activities are not accessible for the user. Instances of frames generated during program execution which describe the object being calculated make up the dynamically developed catalogue of solutions.

In the idea being developed here it is assumed that many application programs completed until now are used and only small modifications of their structure are introduced. That is why in Fig. 1. the data conversion module has been drawn. It transforms the format of information representation in the knowledge base into the form required by the existing application programs and vice versa.

The description of the calculated object in knowledge base consists of information on: (1) its structure, i. e. component elements, the way they are combined; (2) features of the object which have non-numerical values (material, kind of loading and the like) will be further called qualitative features; (3) design parameters (geometric dimensions, forces, stresses and the like) which have numerical values; from now they will be described as quantitative features.

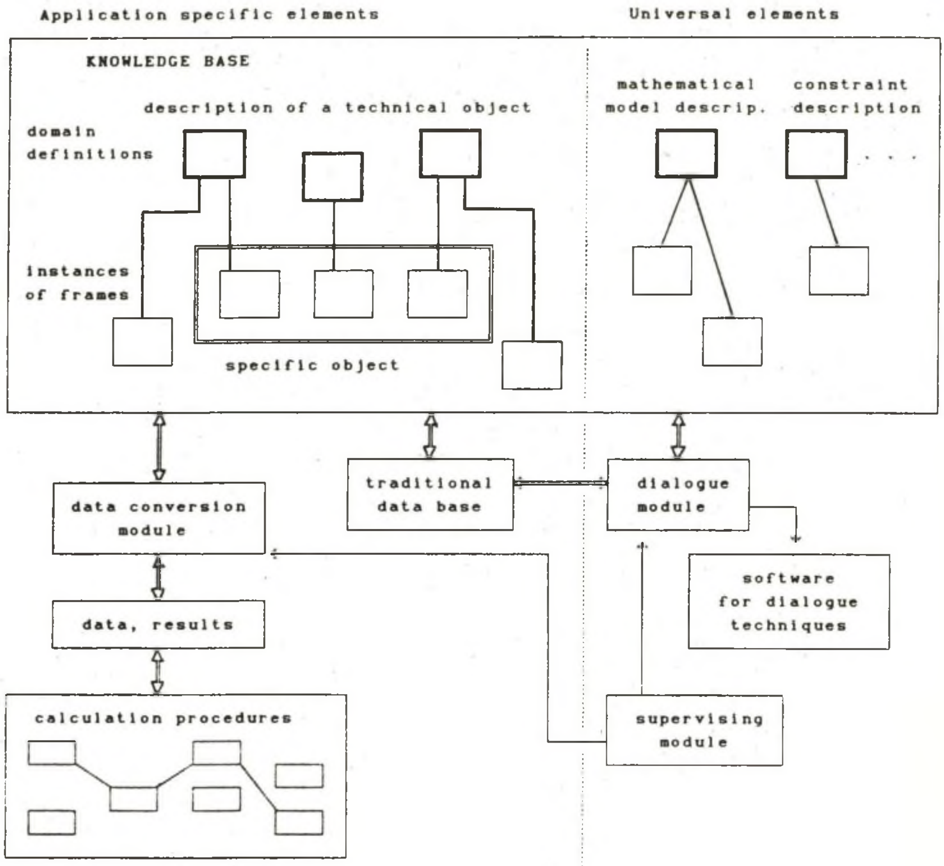

Fig. 1. The structure of CAD calculation program with knowledge base

4. An example of calculations of spring assembly

In this section authors want to point out the possibilities which embedding of the knowledge base into the CAD program gives for the dialogue management. It is shown on the example of calculation of a helical spring assembly how numerous is the set of variants of tasks which the user may formulate in the dialogue due to information and mechanisms contained in knowledge base. The manner of description by means of frames of the calculated object is also presented. Mechanism of generation of instances of frames from the domains describing the calculated object is discussed in brief.

In the example calculations of an assembly of concentric (maximum 3 springs) or of eccentric helical springs with or without the main spring (4 or 5 springs) are considered. The detailed discussion of this technical problem is in [1]. Let us only emphasize here that qualitative features (material, manner of coiling, fixing and machining of the ends) take the same values for all springs.

All the elements occurring in tasks for calculations of a spring assembly which the user may change in the dialogue are enumerated in Table 1, column 2. Kinds of this modification were described in column 3. The task elements are interdependent. These relations are characterized in column 4. In knowledge base they are most often expressed procedurally. In the last column exemplary values are quoted which a given element of task may assume.

From the elements mentioned in Table 1. the following variants of tasks may be formulated. They are illustrated in Fig. 2.

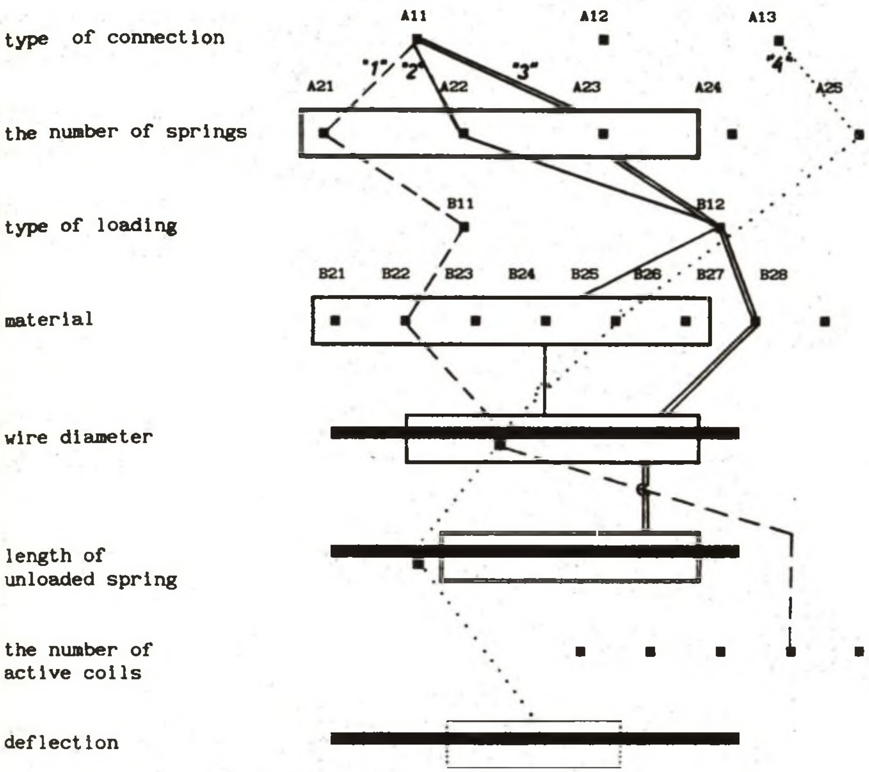

Fig. 2. The variants of calculation tasks for a spring assembly

Task 1 - Construction calculations of a single spring with the given number of active coils instead of the length of unloaded spring.
Task 2 - Construction calculations of two concentric spring assembly with modifying of material and wire diameter by the program.
Task 3 - Optimizing calculations of an assembly of concentric springs with the modified number of springs and wire diameter, factors and length of the springs as decision variables. A complete set of constraints and the criteria: maximum of work performed by an assembly and minimum of the volume of an assembly.
Task 4 - Checking calculations of the assembly of five eccentric springs with the main spring. Deflection of the assembly is varianted, its loading is calculated. Constraint on buckling and increase of outside diameter during deflecting are taken into consideration.

Further considerations are restricted to the description of the calculated object by means of frames. As an example we choose task 2 from among the above

Table 1. Dialogue modified elements of calculation task for springs

No.	Task element	No of vers.	User dialogue activities	Connected elem. Kind of relation	Versions
A	STRUCTURE				
1	the way springs are connected into an assembly	3	pointing to a set of vers.	D,E,F,G - exclusion	11-concentrically 12-eccentrically without main spr.
2	num. of springs in an assembly	5	pointing to a set of vers.	D,E,F,G - exclusion	21-{spring1} 22-{sprin1,sprin2}
B	QUALITATIVE FEATURES				
1	type of loading	2	indication of only 1 version	B2-limitation of the set of vers.	11- static 12- dynamic
2	material	56	pointing to a set of vers.	B1,C6-limit. of the set of vers. C-deter. of val.	21- AI 22- A 23- BI
C	QUANTITATIVE FEATURES				
1	wire diameter	87	pointing to a set of vers.	B2-limitation of the set of vers.	11- 0.07 12- 0.08
2	spring factor	any num.	giving the set of val., defin. num. constraint	—	
3	deflection	any num.	giving the set of val., defin. num. constraint	—	
D	COLLECTIONS OF INPUT DATA			C,F,H- exclus.	
1	wire diam., spr. fact., wire diam pitch diameter	2	an exact vers. - indirectly indicated		—
2	spring length or active coils num (1 spring only)	2	an exact vers. - indirectly indicated		—
3	1 or 2 points on character. given	3	an exact vers. - indirectly indicated		—
E	COLLECTIONS OF RESULTS			H - exclusion	
1	deflection and blocking force	2	indication of only 1 version		11-taken into cons 21-not taken . . .
2	stresses	2	indication of only 1 version		11-taken into cons 21-not taken . . .
F	CONSTRAINTS			C - extending the set of vers.	
1	on buckling	2	indication of only 1 version		11-taken into cons 21-not taken . . .
2	on the increase outside diameter when deflected	2	indication of only 1 version		11-taken into cons 21-not taken . . .
G	CRITERIA				
1	maximum of work	2	indication of only 1 version		11-taken into cons 21-not taken . . .
2	minimum of volume	2	indication of only 1 version		11-taken into cons 21-not taken . . .
3	min of wire mass	2	- " -		11-taken into cons
H	TYPE OF CALCUL.	4	pointing to a set of vers.	D,E - exclus.	1-construction cal 2-optimization cal
G	CALCUL. METHOD		pointing to a set of vers.	D,E,F - exclus.	

mentioned variants of tasks. In Fig. 3. we present the frame with the definition of the task and instances of frames which represent the calculated object. Below we characterize the general principles of creation of instances of frames which describe a specific object.

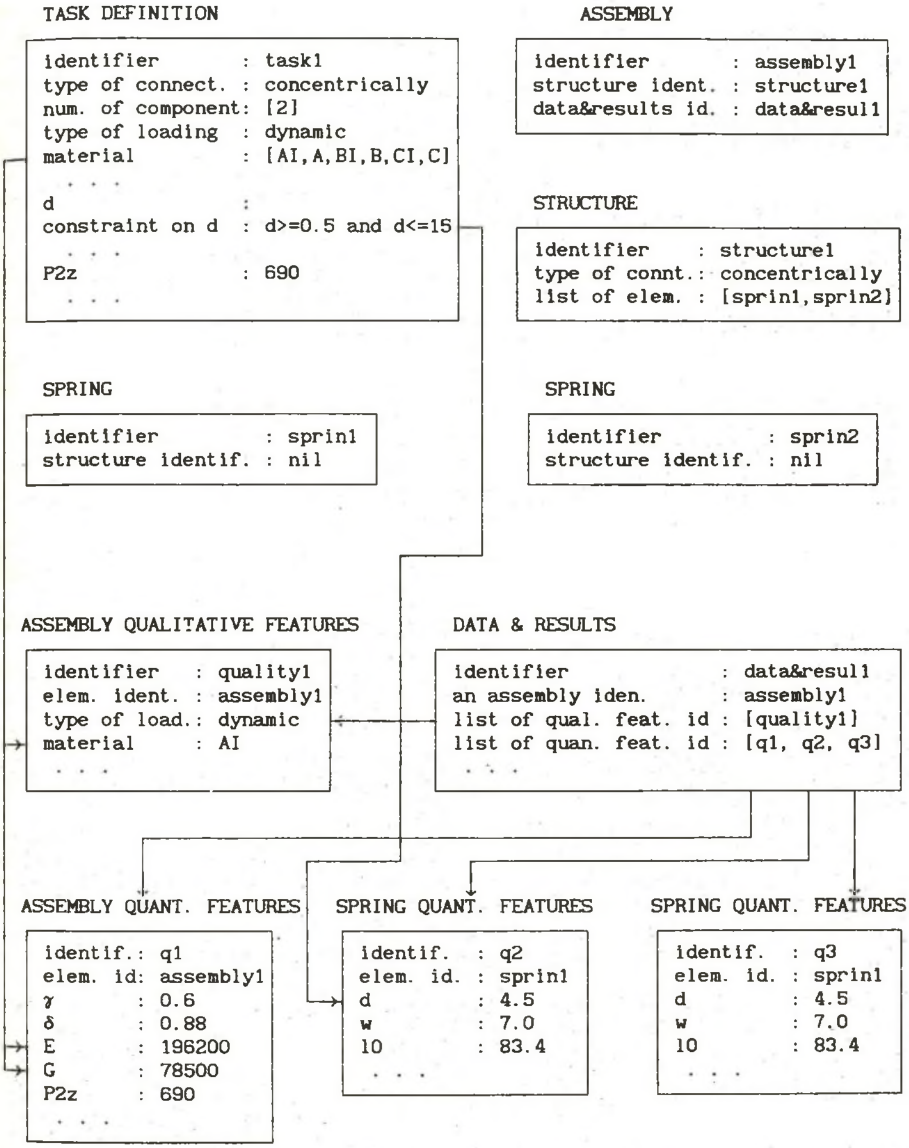

Fig. 3. Instances of frames used in the phase of data preparation for calculations and relations among them

I. The program shows to the user the sets of versions for task elements which he may modify during the dialogue (i. e. the program informs about domains of values for the elements mentioned in Tab. 1.). For every element the user has the possibilities of choice as mentioned in column 4, Tab. 1.

II. Results of the user choices are stored in an instance of the frame from the TASK DEFINITION domain. As can be seen in Tab. 1. the program allows to vary the structures of the calculated object, its qualitative and quantitative features. That is why the values of the attributes of the frame "task definition" may be the lists of elements. Additionally, the user can formulate the numerical constraints on the values of quantitative features. And for the continuous quantitative features defining of a range as domain is allowed.

III. The main domain among all the domains which define the calculated object is AN ASSEMBLY. The operations of which preparation of the data for calculation consists of start from creating an instance of the frame from this domain. Next instances of frames of subordinate domains are generated, that is the frames which are values of attributes of the "assembly" frame.

IV. Every change of the structure or of the feature which characterizes the calculated object requires creation of a new instance of the frame from the ASSEMBLY domain and from subordinate domains. For instance, the change in the diameter of the wire for both springs of which the assembly consists will cause generation of a new "assembly" frame and putting into it an identifier of the previously created "structure" and "assembly qualitative features" frames. Also a new frame "data & results" and new frames containing quantitative features describing component elements will be created.

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KNOWLEDGE BASE UND DIALOG IN DER BERECHNUNGSPROGRAMME CAD FÜR DIE MECHANIK

Zusammenfassung. Die Bearbeitung stellt eine Konzeption für die Erbannung von Berechnungsprogramme CAD mit der Knowledge base zur realisierung mit ger Hilfe der Frame-Technik dar. Man behandelt die Struktur von einen solchen Programm. Man charakterisiert die Informationen über den Verwendungsbereich repräsentiert in der Knowledge base.

BAZA WIEDZY I DIALOG W OBLICZENIOWYCH PROGRAMACH CAD DLA MECHANIKI

Streszczenie. Praca przedstawia koncepcję budowy obliczeniowych programów CAD z bazą wiedzy zrealizowaną za pomocą techniki ram. Omawia się strukturę takiego programu. Charakteryzuje się informacje o dziedzinie zastosowania zawarte w bazie wiedzy.

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