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Modification of Mechanisms from Database for Task Based Conceptual Design Method

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Abstract. In a novel approach of task based conceptual design method by proper synthesis and analyzes tools mechanism and function entities are modified, turned into and considered as extendable and squeezable ones , so systemized search of optimal structural solutions inside those entities leads the designer to satisfaction of prior given set of functions. Conceptual design generation procedure includes task simplification phase where a key function(s) based mechanical model is composed and its further development into final concept requires gradual satisfaction of remained pre given functions. Two major sources of mechanical solutions are used for function satisfaction. First is existing knowledge on mechanism available as database and the second source is self-generation of mechanisms by granting DOF action, both procedures strictly implemented in a function targeted manner. The database itself is available in different formats depending on application, tutorial or systemizing purposes. Current study discloses the approaches and methods of modification of mechanisms from database into models and formats applicable and suitable for being used in proposed task based conceptual design method.

Introduction

Task based concept design is important and challenging part for the whole design process. Well known [1, 2, 3] methods of concept design are arranging a systematic approach to find proper combination of links for satisfying the challenging function. These methods are grouped around a basic idea of separation of function from mechanism [3], According [2] sequence of actions for conceptual design includes selection of an existing design as original mechanism, its generalization by leaving only links and revolute joints, synthesis of an mechanism atlas per number of links and joints, obtaining of specialized kinematic chains by assigning the types of members and joints subject to design requirements, identification of ' acceptable kinematic chains subject to design constraints, particularization of each acceptable kinematic chain into corresponding mechanism and finally removing the existing designs from atlas of mechanism to obtain new designs.Conceptual phase of mechanical design classical and practical theories [4] implies more on practical knowledge rather than formalized methodology of mechanism synthesis. Conceptual solution is also searched [5] as a structure addition to current design by chains from database having the demanded mechanical properties.

Extended knowledge of mechanical design accumulated in textbooks, guidebooks, etc. serves the designers for creation of new devices. Those sources of information are known shortly as database. This kind of literature normally presents the mechanisms classified perfield of applicationfunctional (general, feed, stop movement, guidance, transmission), structural (gear, cam, linkage), kinematical joint (low type, high type), type of mechanism or other signs. From the designer point of view functional based classification is preferable so far functions should be satisfied along mechanical development.

The available database either has encyclopedic nature [4], [5] or have systematic alphabetic contents [6] either has dual structure / functional format [8]. Freudenstein[3] and Tsai[2] suggest generation of structures based on a single function topology while the other functions are under classified into limitations and constraints. In Kraynev's guidebook [6] both functions and solutions are present, however designer's extra effort is required for morphological analyzes and for translating availableinto a basic or key function. In many theories of mechanical design (Sandor-Erdman [5], Ullman [7]) the user finds general recommendations about usefulness of database search, but less techniques for formalization and application of knowledge in mechanical science.

The classification based on solutions, structures, kinematical joints and other features are not providing the designer the answer he needs more: clear out the bare function behind the structure and see the structure behind the mechanism. This abstraction or formalization is left as additional load on the designer to be done by heart or by extra effort. In some cases that's not so difficult to notice the main function behind the demanded one. But in the most cases the functions are hidden. Not only the functions are hidden also the kinematical joints and the links are hidden so tracking the mechanism structure along with evaluating and revealing the functions is really difficult.Here we may formulate the main objectives of this study: how to modify the database into general and most useful set of functions? And how modify the mechanism prototype solution into a format that will contain the main function solely?Morphological modification for function and structural modification for the mechanism could be useful for providing the design process with demanded mechanism-function options.

Key model and database modification techniques

An alternative concept design method based on 30 more years design experience issuggested where the novel design search starts by creation and consideration of a prototype or model physically and/or virtually satisfying one or a set of required functions[9]. The model is built by modification of a prototype mechanism or by function based connection of links by kinematical joints. In both cases should be followed mandatory requirement of consideration and further satisfaction of specific challenging functions. Thus direct dependence between function and mechanical entity is established - a necessary and essential condition of proposed task based design method, a condition that needs to be present at all stages of concept design. The prototype model presenting key functions of future mechanism differs from it by its incompleteness of structure which is subject of final development for satisfaction of the remained functions. Methodically the procedure of prototype model completion and modification into final concept design is based on usage of same prototype creation methods which is another important and specific feature of the proposed method providing unification and simplicity of applicable synthesis tools.

As the experience shows the same methods for both mechanical and functional field modification could have proper modification and further used for database modification and application. Two procedures including the key models and the techniques for conceptual design and database modification are disclosed here below.

The database modification procedure can be considered as the reversed one of conceptual design so far the synthesizing actions for building a mechanism per demanded functions are reversed to analyzing actions for clearing out the mechanisms and the groups of the links which are included in the given known structure from database for implementing the functional mission of the mechanism. So the objective should be clearing out the kinematical joints and other types of link interaction by imposing (exposing) them in standard kinematical joints and mentioning specific groups of the links which provide a single or a set of functions.

Two major modifications or translations for mechanism and for function should be translated. In the case of mechanism this modification extends to translation of the mechanism to a basic one like four bar mechanism, prismatic or revolution joint, screw mechanism, etc. and in the case of function, the original function claimed by the mechanism should be translated into a more mechanized one, which could be "understood" and implemented by the basic mechanism.

As a result a set of sub functions and sub mechanisms are created, where the second set is explaining the first one with two major results: first the given mechanism could be easier explained by simpler sub mechanisms and sub functions, and second, designer gains more knowledge about still unknown for him options of application of basic or set of basic mechanism for specific functions.

Table 1 Summary of procedures for task based conceptual design and for mechanism modification from database

Conceptual Design		*Database Modification*	
Key Model	$M_{i,j} = D[F_{k,l}]$	*Key Model*	$M_{i,j} = D[F_{k,l}]$
$M_{i,j}$: Mechanism (Mechanical) entity			
F_{kl}: Function entity			
i, j: Position of a single link in matrix description of mechanical entity $[M_{i,j}]$			
k, l: Position of a function in matrix description of functional entity$[F_{k,l}]$			
D: Symbol for direct dependence between mechanism and function			
$M_{i,j}$is synthesized according given set of F_{kl}:		$M_{i,j}$is revealed and explained according given s of F_{kl}:	
Translate a function	$[F_{k,l}] => [F_{k+1,l}]$	*Translate a function*	$[F_{k,l}] => [F_{k+1,l}]$
Function is translated to hierarchically neighbor one for explanation or implementation			
Plan a function	$M_{i,j} = D[X_{i,j}F_{i,i+1}X_{i+}$	*Discover a function*	$M_{i,j} =$ $= D[X_{i,j}F_{i,i+1}X_{i+1,j}]$
$X_{i,j}$:Previous link,$X_{i+1,j}$: Next link,$F_{i,i+1}$: Function			
Function is planned to be implemented by mechanical means		Function is identified according prese mechanical means	
Synthesize a mechanism by given function	$M_{i,j}$ $= D[X_{i,j}T_{i,i+1}X_{i+1,j}]$	*Identify the mechanica entities explainingthe translated functions*	$F_{k+1,l}$ $= D[X_{i,j}J_{i,i+1}X_{i+1,j}]$
$T_{i,i+1} = [f, c, d]$: Synthesis tools: f: functions Grant DOF c: apply paralel kinematical chain d: condition mechanism with a drive		$J_{i,i+1} = [P, R, C]$: Types of kinematical joints: P: prismatic joint R: revolute joint C: cam joint, etc.	
Function and mechanism pick up	$M_{i,j} = G[M_{i,j}] =>$ $=> g[M_{i,j}]$ $F_{k,l} = G[F_{k,l}] =>$ ⇨ $g[F_{k,l}]$	*Function and mechanism pick up*	$M_{i,j} = G[M_{i,j}] =>$ $=> g[M_{i,j}]$ $F_{k,l} = G[F_{k,l}] =>$ ⇨ $g[F_{k,l}]$
G: Symbol for matrix description of mechanism and function g : Symbol for picked up entity mechanism and function			
Evaluate two conceptual solutions of $M^A_{i,j}$*and* $M^B_{i,j}$	$M^A_{i,j} = D[F_{k,l}]$ $<=>$ $M^B_{i,j} = D[F_{k,l}]$	*Evaluate mechanisms* $M^A_{i,j}$*and* $M^B_{i,j}$ *of two similar or competitive devices*	$M^A_{i,j} = D[F_{k,l}]$ $<=>$ $M^B_{i,j} = D[F_{k,l}]$

All the steps of mechanism and function modification are shown and formalized in the Table 1.

Example: Modification of door lock mechanism from database

A door lock mechanism from [K] mechanism guidebook, page 117, is modified according techniques described above. This is a regular door lock mechanism, which we need to modify in two aspects. Translate the announced and known functions into sub functions and built mechanical chains that will explain those translated sub functions. Table 2 starts with physical diagram of the lock mechanism and continues with 3D diagram with indication of all the necessary and function explaining kinematical joints. Table 3 includes the link nomenclature, mechanism functions presented in both regular function tree and in special matrix formats. This table is ended by a special format of dependence formula showing in an extended way all the links and kinematical joints. Should be noted that for both mechanism and function are described in special formats allowing usage of matrix table for mechanism, matrix and for both categories. Symbols for repeated links are taken into parentheses.

Table 2 Physical and modified diagrams for door lock mechanism

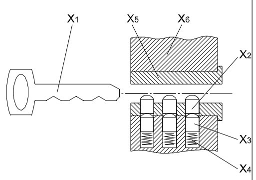
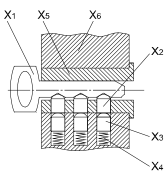
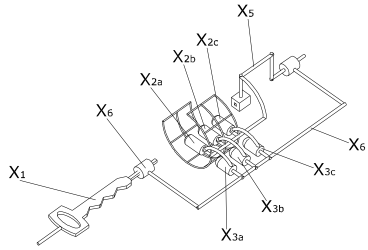
Physical diagram		Modified 3D diagram
		

Table 3 Link nomenclature, set of translated functions and dependence formula

	Nomenclature for links	Set of primary(1-5) and translated (6-10) functions					
X_1	Key						
X_2	Key pin			F_1	Open	F_6	Separate
X_3	Door pin			F_2	Close	F_7	Join
X_4	Spring (shown in physical diagram only)	F_0	Door Lock	F_3	Secrecy	F_8	Uniqueness
X_5	Heart			F_4	Resistant	F_9	Bear load
X_6	Door			F_5	Keep key away	F_{10}	Insert

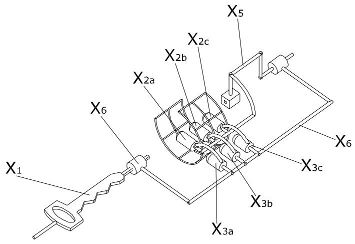
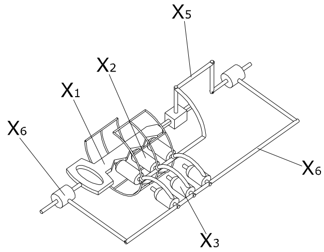
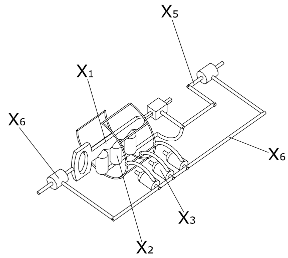
Translation of functions: matrix format	Dependence formula
$\begin{bmatrix} F_0 & F_1 \\ (F_0) & F_2 \\ (F_0) & F_3 \\ (F_0) & F_4 \\ (F_0) & F_5 \end{bmatrix} => \begin{bmatrix} F_0 & F_1 & F_6 \\ (F_0) & F_2 & F_7 \\ (F_0) & F_3 & F_8 \\ (F_0) & F_4 & F_9 \\ (F_0) & F_5 & F_{10} \end{bmatrix}$	$\begin{bmatrix} X_1 & P & X_5 & R & X_6 & P & X_{3a} & P & (X_5) & P & X_{2a} & C & (X_1) \\ . & . & . & . & . & (X_6) & P & X_{3b} & P & (X_5) & P & X_{2b} & C & (X_1) \\ . & . & . & . & . & (X_6) & P & X_{3c} & P & (X_5) & P & X_{2c} & C & (X_1) \end{bmatrix}$

Table 4 serves to pick necessary areas from dependence formula from Table 3 for using them to explain specific functions that the door lock mechanism has. For satisfaction of function F_7 *- Join,* for example, the fragment of extended dependence formula $[X_3 \;\; P \;\; X_5]$ is separated, which shows that the door pin X_3 moves along its axis in the door to continue its movement in the slot of heart X_5 heart joining thus the heart and the door and providing the locked condition of the door lock. Symbol *P* is for prismatic joint composed by named links of X_3 and X_5.

Function F8- Uniqueness in its turn is provided by highly random combination of depths h_a, h_b, h_c in of door pin X_3 ends entering into the body of heart X_5 and providing fixed condition of the door and heart. The values h_a, h_b, h_c are defined as sliding (translational) movement parameters of the prismatic joint *P* between the links of X_3 and X_5.

Modified functional mechanical data from Table 3 is sufficient to describe the remained functions Bear Load and Insert, as well other functions that could describe the door lock and could be revealed along with detailed design of this product.

Table 4 Modification of mechanism of a door lock

Identification of translated functions:		
F_7 - *Join*	F_6 -*Separate*&F_{10} - *Insert*	F_8 - *Uniqueness*
		
$[X_3 \;\; P \;\; X_5]$	$[X_3 \;\; P \;\; X_5]$ $[X_1 \;\; P \;\; X_5]$	$\begin{bmatrix} X_{3a}P(h_a) & X_5 \\ X_{3b}P(h_b) & X_5 \\ X_{3c}P(h_c) & X_5 \end{bmatrix}$
$[X_3 \;\; F_7 \;\; X_5]$	$[X_3 \;\; F_6 \;\; X_5]$ $[X_1 \;\; F_{10} \;\; X_5]$	$\begin{bmatrix} X_{3a}F_8 & X_5 \\ X_{3b}F_8 & X_5 \\ X_{3c}F_8 & X_5 \end{bmatrix}$ $\{h_a, h_b, h_c\} \neq \{h_b', h_b', h_c'\}$

Conclusions

So far the available database (book, guide book, mechanism atlases and database) are built and classified according different classification principles the database modification task is a demanded and necessary task for understanding, explaining and application of database resources.

Mechanism and function modification follows the aim to present them in a status and format which makes convenient comparison of those mechanism to similar or prototype solutions which is practically difficult and even impossible without suggested modification.

Mechanism modification techniques implies addition of newly built mechanical chains as well reduction and squeezing of existing chains per functional or methodical demand, depending on status of mechanism or depending on the action of mechanism which is under consideration.

Formalization formats for morphological modifications are developed and along with mechanism modification means according earlier presented conceptual design method are applied that implies and provides a single methodical base and approach for the both procedures.

The data modification and application principle can be developed and applied for mechanism database classification per functional signs.

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