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Method of ranking in the function model

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Abstract

At present function analysis is often used for system analysis and concept design development. Function analysis is based on modelling technique and rules of model modification, the most known of which is trimming. Trimming operator suggests system simplifications after each element of it is given a rank. . Thus, the core of the trimming is the evaluation criterion.
The article compares two known ranking methods (Gen3 method and method of Miao Li) and suggests a new method of ranking of elements in the function model. Exemplary mechanical system design analysis shows how different ranking approaches influence the trimming procedure. The method can be used for CAD/CAM software at the stage of conceptual design for automatic and semi-automatic system simplification.

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1. Introduction

Methods for systematic conceptual design have always been in the focus of research especially since the whole design became software-frameworked. Obviously, systematic approach means certain formalism of analysis based on modelling and model transformation formalism. One of the most reasonable modelling techniques (neither based on powerful but complicated mathematical nor simple but unformal natural language models) is known to be function modelling [1]. In fact, the usage of function models enables “top-down” and “bottom-top” design style. On the other side, there are CAD system development trends to use TRIZ elements in them, or there are works with the 3D solid body models using TRIZ [2].

Currently there has been some progress in the area automated design tools development. The focus is algorithms and tool for systematic design ideas generation, troubleshooting, design transformation and simplification etc.

For example, GoldFire™ software by Invention Machine presents tool to patent design around from [3]. The product supports functional modeling performed by user or even partially automated manner from the text of the patent or another technical document, then the user performs ranking and the software suggests the elements for trimming. We should notice that big data or more precisely literature based discovery studies attack similar but slightly more general problem. They focus on extraction the concept (e.g. contents, ontology, hierarchy, interactions, subject-object action triples, cause-effect relationships, function model) from the textual data.

Another idea to automate the function model design was to use CAD environment, which is standard interface for system data processing in engineering world. The study [2, 4, 5, 6] presents an approach and working prototype of software that automates the function model extraction from 3D SolidWorks CAD assembly, and assist further function ranking and trimming.

It is quite possible that the progress in the field will deliver algorithms that are able to design function model (knowledge) of an engineering system from patents, pictures, texts etc. (information). Similar revolution was brought by powerful computers in 90s, when the design of certain types of mathematical models became almost automated due to blending of finite-element approach with graphical system description.

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The goal of the function modelling is to analyze the product we are going to improve. At present, there are great number of methods for assessing the function model such as the solving complexity factor [7], the value engineering [8] etc. All these methods share a common trait to focus on the product model with selected elements only.

There are three steps to design the functional model of a system [9]: the component analysis, the interaction analysis, the function analysis. Having designed the function model we can systematically derive models for simplified design by trimming.

Let us consider the function ranking and the trimming in detail. 3 ("A, B, C") or 6 ("A, X, B, C, D, E") rules are often used for the trimming [10]. It should be noted that these usage is directly related to the rank of the functions. The element with the lowest rank is the first candidate for trimming. The application of the formalized approach simplifies "manual" trimming procedure applications and may serve as the basis for design automation.

2. Description of methods

2.1. Definitions

We are going to use the following definitions throughout the paper.

- The rank is defined by the ranking factor. The more ranking factor has the higher the rank.
- The more useful (or more used) functions (elements) obtain the higher rank, the useless (or unused) functions (elements) obtain the lower rank.
- The rank is evaluated by integers from 1 to ∞, where the function with the highest rank obtains the value 1. So, the higher number has the lower rank.

2.2. Classical method of ranking

This method is widely used for systematic inventing [11, 12, 13].

The higher rank belongs to the functions that are closer to the key function in this method. So, we choose the furthest from the target functions as the candidates for trimming. For example, tooth brash bristles are of the highest rank, but the rubber cover on the handle is the lowest rank. Thus, the method may lead to the situation when the highest rank belong to an element that is geometrically close the target but does not perform any special function. For example, a sheet of paper laying on the chair would have the highest rank while adding nothing to main function of the system "to hold".

2.3. Linear convolution (Method of Miao Li).

To evaluate the Function level points (ranking factor) of each component in this method Miao Li [14] introduces the function level score. For example: Useful function (5 point), Harmful function (−5 point), insufficient function (3 point), Excessive function (−3 point). Besides, the importance factor of each function level can be assigned based on expert's opinion and practical situation.

If one component performs 3 useful functions, 1 harmful function and 2 insufficient functions to other components, and the importance factor of each function level are all equal to 1. Therefore, the component function level points is 16 points ($3 * 5 * 1 - 1 * 5 * 1 + 2 * 3 * 1$). Let us assume the total cost of the system is equal to 100, the cost ratio of this component is 10%. So the component relative cost gets 10. At last, by evaluating each component functionality points (function performance level points over relative cost), the total function rank of the engineering system components can be obtained. The higher score indicates that the component has more functionality. The lower score means that the component has not so much functionality, which gives a higher priority for Trimming.

Interestingly, the author prefers using rules A, B, C for the trimming instead of this method [14].

2.4. New method

The above methods have a significant drawback – they are not able to highlight useful elements. Thus we suggest the following approach for ranking.

- The closer function is to the target function, the higher is its rank (as the classical method of ranking – 2.2).
- The more connections, associating the element with the function, the higher rank each function has.
- Duplicate functions obtain the lower rank (for example, 2 nails are holding one board, the function "hold" of each nail has the lower rank).
- The farther element is from the key element (geometrically) the lower rate it has.

3. Case study

As an example, let us consider the concept, designed to verify the modes of polishing in the TERMOTRONIC firm (St. Petersburg, Russia) [15]. The aim of the development was to check what regimes were the best for polishing of the flowmeter "Piterflow RS" electrodes. This device was not used for industrial electrode polishing, but only to verify the modes of polishing such as the speed handle, the composition of abrasives, the processing time, etc.

3.1. Device description

This design of this device was inspired by contact lens polishing system [16, 17].

The device comprises two main systems – a rotation system, and a swing system. We have treated only the swing system by the trimming. The rotation system consists of a spindle (for a hold electrode) and an electric motor rotating a spindle.

The swing system design is presented in the figure 1. The main swing system function is to move the mount that sets in motion the pillow with abrasive, polishing the head of the electrode.