DEVELOPING THE SUPPORT FRAMEWORK SYSTEM OF SPECIAL PURPOSE MACHINES DESIGNING

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Abstract. From the customer side the requirements of the special purpose machines are getting more and more diversified and complex year by year. Could it be possible to make a design support frame-software in this field? An expert system will be shown in this paper, which is based on previously built machines. The machine parts and subassemblies are stored in a database. The possible contacts between these subassemblies are presented in a knowledge base. The purpose of this expert system is to offer a valuable help for the design engineer when a new machine plan is needed. The program output is the bill of material which contains the required subassembly, and even the cumulated price.

1. Introduction

There are many special fields in mechanical design engineering but to design and build a special purpose machine is always a challenge because the customer requirements change during the design and building or even after the delivery. In the beginning the customer has a problem - and sometimes a theoretical solution - to solve. Creativity and individual concepts are the first items of the long list of necessary skills to find fast, cheap and reliable machine designing for them. Becoming an expert mechanical engineer is an expensive and long process. In this paper you can find an idea about how to help mechanical engineer with expert systems and it shows the direction of the future of machine design.

1.1 Concept of the level of automation

If we want to step forward from an actual automation level to the next one, we need to analyze the working process of the actual manufacturing machines. To make this upgrade it is necessary to make a quantity change. There are many concepts in the literature and we embedded ours in them. Our focus is to find feasible solutions for this “quantity jump” in the field of special purpose machines. The required result by the customer is a flexible workstation on supervising level. [1,2] You can see our vision in figure 1.
1.2 Choose the focus of the development

For the first step we must start with a single and well definable group of machine. We have chosen welding machines. There are many products which contain a welding process, so welding machines belong to a lot of product lines. Electronic components like resistors, capacitors, contacts are required to be fixed to the leadframe or each other. Welding is an optimal solution for fixing electrical components with the required quality of the contact. Resistance welding requires less number of equipment than soldering, because no additional material is needed. Depending on the part orientation in the product it is possible to weld only from one side with two electrodes, but sometimes electrodes are needed to contact from the top and bottom as well. Defining the parts of the machines is also important to start the work. This kind of machines contains general elements, such as machine frame, machine table, welding head, fixture for the part, movement for welding head and fixture, safety cover, electrical cabinet, PLC and HMI (human machine interface). Apart from these, there are options also available for the machines like fixture ID, part fixation in the fixture, electrode ID, indexing table, PC control, operator light, automatic reject handling, automatic part ejection, quality control with camera and so on. It could be easy to make a configuration mechanism for this kind of design, but the problem is in our field (special purpose machines) that it is impossible to design every single aspect of the customer requirements in detail. We need a more complex software than a configurator. The software must find the closest "adoptable" subassembly which is available. This will be a valuable help for the machine designer and the design time
will be reduced. Our expert system helps the design engineer to use the existed models and modify or change the necessary parts only.

2. Expert systems

The expert system has been in use for a long time. Analyzing data (not big data this time) and using the rules keep this concept simple and useful.

The main idea behind this kind of systems is the following: making a separation between the data and the inference engine. There are the initial data and rules with logical contacts and iteration when these rules can „fire”. After this step there are updated data and different sets of rules, and a new „fire” process is coming. When there are no more data or rules, the iteration is over. [3] The remaining data is the solution. There are framework systems for expert system and we call them shells. A typical shell is a text based user interface. However, we have not implemented our system in a shell. We made a graphical interface which can be seen in figure 2.

![Figure 2. Screen from our developed expert system UI](image)

Expert systems are used in a wide range of different fields. One of them called KBS (Knowledge Base System) is developed to give assistance to engineers who design agricultural machines. It begins with the design rules, standards, formulas and 3D models. Developers divided the knowledge base into two different parts: physical elements and technical experience. To store the data during the implementation, an SQL database system was used. The complete hybrid system uses an object oriented method. [4]

2.1 Modeling structures and data system

How can we make machines from a list of requirements? Actually, this is a long and costly process. If every single machine is individual - and for special purpose it is a must – the design time could be growing at an unexpected rate. Manufacturing the parts is a challenge as well. The engineer's contribution is needed even at the assembling. How can we reduce this well trained engineer's time? One concept is to use algorithms to make the variations of the structures,[5, 6] Another one is that the design process starts from the existing machines. [7] We will follow a hybrid method of these two.
To begin with the whole machine, it contains many components. These less complex structures include commercial and manufactured parts. We call them subassemblies in our terminology. A data structure for these subassemblies is required to see which part belongs to which assembly. Every single part must be an individual identifier, not just the drawing number, but the database ID, too. The object oriented method is used to store these data. Every object has methods to read the data from the knowledge base and store the unique properties. From the bottom to the top, we start with the individual parts and on the highest level with the main assembly. There are machines which contain a group of subassemblies, while other machines use totally different group of subassemblies. How could these be used to make an expert system to support the engineer? We have found a new concept to keep the flexibility but use the elements which are already designed. Figure 3 shows an overview of our framework system.

2.2 Fuzzy system, knowledge base

To unlock the limitations we used the following concept. Theoretically, every subassembly could be installed in every imaginable machine. The question is how long it takes to modify the design to put the re-designed subassembly into the new machine ordered by the customer. This design period is typified by a number and defined by the design engineer of the subassembly. Actually, in our concept this number follows fuzzy logic. The fuzzy concept is the following: how much a randomly chosen subassembly belongs to the set of the new machine subassemblies. If the component design does not need to be modified, then the value of the installation is 10. If it takes only a couple of hours, this value is 8 or 9. If the complete design needs to be changed, it is 1. If it is not possible to use that certain subassembly in the current machine, the value is zero. Arranging this data into groups was necessary to organize the subassemblies. In the figure 4 it can be seen a sample of this knowledge base.
To configure out the new machine there are some screens in the program. You must follow the screens and figure out which function is needed by the customer. After this configuration this input data is transformed into a pattern, to follow the fundamental of expert systems. This pattern contains the main components as one can seen in figure 5. It is just visualization behind the concept, but it could be very useful to understand how the system works. Yellow cells represent the required component, green cells are irrelevant in this search scope. For example “0” means that the machine structure is XY table, “1” means that the machine structure is double XY table and so on.

In figure 6 a simplified visualization of one subassembly pattern can be seen. Realizing the rules is implemented by comparing this base pattern with the patterns of the components cell by cell.
2.3 Choosing methods

To choose a certain object from the knowledge base is another issue. There are attributes e.g. difficulty or price. The program can only select from the subassemblies in the same group. The concept is the following: in a cycle every subassembly compared to the base pattern. Those which contain equalities (meaning 10 to 10) are chosen and put into a temporary array, named elected array. This is similar to a rule that can "fire". If the customer wants a machine with double XY table, those subassemblies will be chosen which are compatible with this criteria and has the number 10 in cell 1. If there aren't any components with 10 (100% compatibility), the program will search for 9 and so on. After the cycle process only one step is needed over the whole knowledge base. Search through this elected array and check if there are more than one subassemblies are chosen from every group. If so, we need to choose the cheapest and delete the others. The result is: one array which contains one subassembly (the perfect one) to every required group. If the price had been added to the knowledge base, the program could have calculated the sum of the cumulated price. In the concept there is a data structure behind the knowledge base and based on that data the bill of material which contains the parts needed to manufacture for the new machine is available. Presently, this BOM is only a list, no geometric modeling is available behind these results. When the new machine has been designed, all the new subassemblies must be uploaded to the knowledge base. After each machine design, the knowledge base becomes larger and thus a growing knowledge base is available.

3. Summary

To summarize the work, we can say that the system was working with test data, however; this program is still a development platform which verifies that the theory could be working on much more difficult machines as well.

3.1 Future plans

Based on real world problems the next goal is to extend this system for many machine groups. Keeping the already designed parts and assemblies is important, but not vital. There are other cutting edge technologies in engineering, e.g. generative design and 3D printing. The next big step is, based on the necessary assembly modification, to design the new required parts directly by the program. Design
engineering is not a job that could be replaced by an artificial intelligence in the near future, but engineers who use an expert system could become much more effective.

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