Genus Software

Automating Repetitive Engineering Tasks

The first response of any engineer when discussing design automation is: "You can't automate what I do." And they are right. However, I would state it more positively: "An engineer's time is too valuable to waste it doing things that could be automated."

So how do you know what can be automated? That is a function of the nature of the problem, and the tools used to solve it.

The purpose of this document is to introduce the terms necessary to classify both the engineering tasks and the available tools, and set realistic expectations as to the amount of automation that is possible. After making the distinction between acceleration and automation, the different types of design (custom design, design for mass production and design for mass customization), and the different types of tools (master-model configuration, generative configuration and search), we will discuss how to select the right tool for the problem, not bend the problem to the tool.

Acceleration vs. Automation

Tools that accelerate a process allow the user to do more work in less time, but do not change the process. While it is often said that because a process now runs quicker that it has been "automated", I prefer to reserve the word automation to mean completely eliminating a manual step from the process.

For example, moving from pencil and paper to 2D CAD accelerated the drafting process, but did not eliminate the need for a draftsman. On the other hand, 3D solid modeling put a tool in the hands of the engineer that automated drafting. A 2D drawing based on a 3D model updates automatically when the model is changed. The process has changed. It is no longer necessary for the engineer to mark up a drawing and send it to a draftsman for revision.

Acceleration and automation both play a role in eliminating engineering bottlenecks. The former makes the engineer more efficient, the latter eliminates work that only the engineer could do.

Engineering Design

What characterizes a design problem is that there is more than one approach to solving the problem, and for any given approach there is typically more than one solution. The role of the design engineer is to find the optimal solution given the available resources.

Mathematically speaking, the customer's performance requirements leave the problem under constrained. Using a process that is largely trial-and-error, the engineer considers other factors such as cost, raw materials, tooling, and time, to identify the "best" solution for each customer.

For the general custom design problem, the quality of the result is dependent on the skill and experience of the engineer to make educated guesses. Solid modeling and analysis tools can accelerate the process, shortening design time, or allowing time for additional iterations to further refine the solution. Custom "one-off" design is a creative process, and is not amenable to automation.

Pre-Engineered for Mass Production

Not every customer can afford the time and expense of a custom designed unique solution to their problem. For many, "good enough at half the price" is an acceptable trade-off.

Mass Production techniques allow a manufacturer to achieve significant gains in production efficiency, at the cost of limiting product variations. Product is purchased off-the-shelf, and an engineer is never involved in the sale. This is not because the product did not require engineering, nor is it because the engineer's task has been automated. All the engineering decisions have been made before the product goes into production. The time and expense of engineering is amortized over a large volume of sales.

The customer may be offered limited configurability of the product, choosing from a subset of pre-engineered options. A sales configurator can accelerate the sales process, by presenting alternatives in a logical order, and by identifying (or preventing) the selection of an invalid combination of options.

Mass Customization

The goal of Mass Customization is to design and manufacture a unique, cost effective solution for each customer, and to deliver this solution in the same time frame as a configured, mass produced product. A manufacturer who chooses to implement Mass Customization gains the competitive advantage of being able to deliver the greatest value at the lowest cost to their customers.

With the advent of NC machining and Additive Manufacturing techniques, manufacturers now have the flexibility to efficiently produce products in short runs. The barrier to delivering a custom solution at an affordable price is the time it takes to engineer each product to order.

For a mature product with a well understood design process, the tools exist to accelerate and/or automate engineering design, allowing manufacturers to fully realize the benefits of Mass Customization.

Accelerate Design with Configuration

Any design can be represented by a set of parameters. Given the parameters, you can reproduce the design.

A parametric CAD system allows a user to create a 3D Model, and will automatically update that model when any of the dimensional parameters (length, angle, quantity) are changed. While some of these dimensions will become design parameters, many must be looked up or calculated using rules. The design parameters driving these rules are not just dimensions, but may include things such as loads, speeds, capacities, materials, etc. In a CAD system alone:

1. There is no interface to enter the design parameters.
2. There is no place to organize the rules.
3. There is no way to reference external data.
4. There is no way to create other output reports, such as: inspection, costing, where-used, etc.

The purpose of an engineering configurator is to overcome these limitations and allow for the creation of a true parametric design. Such a tool allows the engineer to quickly evaluate the consequences of changing a design parameter, accelerating the design process.

Master Model Configuration

One approach to configuration is to create a pre-built master assembly containing everything that might ever be needed. Rules are used to suppress or delete anything that is not used, and to set the values on the remaining dimensions.

There are certain problems with the Master Model approach to configuration. Because every alternative must be present in the Master Model, this approach does not work well for open-ended design problems. Configuring a single awning to be attached to the outside of a building is a straightforward configuration problem. But if that building can have more than four walls, and there can be multiple awnings attached to any wall, creating a Master Model becomes quite difficult.

As the number of permutations and combinations get large, the Master Model itself becomes difficult to maintain, or even create.   Care must be taken to be sure that no part or feature in the model is dependent upon any other part or feature that might be deleted.

Generative Configuration

An alternate approach to creating a Master Model is to start with a blank page, and generate the desired assembly by using rules to combine features to make parts, and parts to make assemblies.

The Generative approach to configuration simplifies the modeling that must be done in the CAD system, but is not without its own limitations. Performance at runtime is slower, as you must wait for each part to be inserted and mated into the assembly.

With a Master Model, a master drawing can be created from the master assembly. Deleting a feature from the model will also delete the appropriate dimensions from the drawing. When a feature is generatively inserted into a part, the corresponding dimensions must also be generatively inserted into the drawing.

Automate Design with Search

Once you have a true parametric design, the question becomes: For a specific customer’s problem, how do you find the parameter set that describes the optimal design for that customer?

The list of all the design parameters and their allowable values define a design space. To systematically search that space requires a tool that can:

1. Generate all the possible design variations.
2. Eliminate invalid alternatives.
3. Score and rank the valid designs.
4. Identify the best design.

With a search tool, the only inputs are the customer's requirements. The system returns multiple solutions, all of which are guaranteed to meet those requirements. Although the system can recommend what it thinks is the best design, the final decision is in the hands of the operator. No engineering expertise in the product or process is required. The design has been automated.

Match the Tool to the Problem

To select the appropriate automation tools, some questions must be answered. Who is the intended operator of the system? Is the objective to fully automate, or just accelerate the process? What is the level of complexity of the problem?

Configurators accelerate, they don't automate. Accelerators make the operator's job more efficient, they don't remove the need for a skilled operator. Therefore, you cannot put an engineering configurator in the hands of a salesman. If the system is to be deployed in sales, the engineer's work must either be pre-engineered, or automated. If the system is to be deployed in engineering, the engineer's work can be either accelerated or automated. If the customer provides only their requirements and the design is done in-house, it can be automated. If the customer is performing some or all of the design and is providing design parameters, the remaining work can still be accelerated.

Most of the CAD add-in products advertised as "Design Automation" tools are only Master Model based configurators, with no support for Search. When operated by an engineer, such a tool can significantly accelerate the design process, provided the problem is not open-ended or otherwise too complex.

To better handle complexity, look for a tool that supports both Master Model and Generative configuration. Ask for a demonstration of how rules are used to insert and mate a component into an assembly, or a feature into a part. If the configurator can't do it, then it is only Master Model based.

To automate, you must model not only the product, but the process by which it is designed. A configurator can't automate, because it can't iterate, and it can only produce one result from a single set of inputs. Ask for a demonstration of how rules are used to iterate and compare and rank alternate designs. If the tool can't do it, it is just a configurator.

True design automation requires a parametric CAD system, a configurator that supports both Generative and Master Model based configuration, and a tool that can define and search a design space. If the design process is understood well enough that one engineer can teach another how to do it, it can be fully automated.

Genus Software, Inc. • 30670 Bainbridge Road, Suite 20 • Solon, OH 44139-6402 • USA • 440.519.2902 • genussoftware.com