IM11234

# Goal-Driven Design: Using Simulation and Optimization in the Design Process

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## Learning Objectives

- Understand where optimization can fit into the design process
- Understand various types of design optimization
- Understand the basic workflow for completing a topological optimization on a structural part using Project Arro

## Description

Traditionally CAD and CAE have mostly been used for documenting designs and providing feedback on how they perform in operation. Improved tools, expanded computing power, and new manufacturing technology are now opening up possibilities for computational design and engineering, where CAD and CAE are used to actually generate part geometry directly. These tools help engineers explore an array of design strategies and create lighter, stronger, or more-efficient parts by driving the design with functional goals, not just a handful of dimensions on a sketch. This course will provide some context for optimization tools as they exist today and introduce several new tools aimed at this goal-driven design concept.

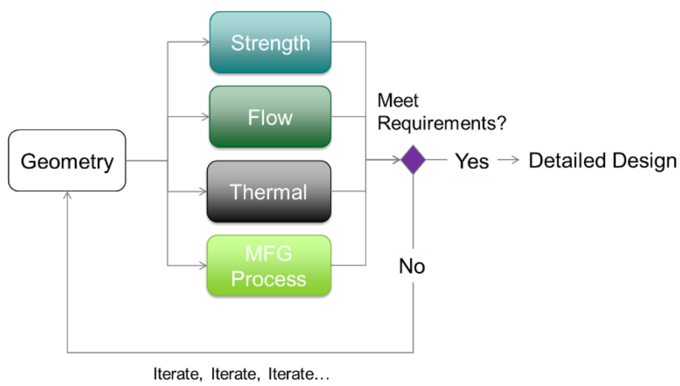
## Your AU Expert

***Mike Smell** is Simulation Product Manager at Autodesk, focused on the future SimStudio platform. Prior to joining the Simulation Product Management team this year, Mike had spent his last 3 years as Technical Account Manager in Autodesk's Manufacturing Named Accounts program, where he was working with customers to help them identify and solve business challenges with Autodesk solutions. Mike has spent nearly 10 years in the CAD and CAE industry, starting his career at Algor, Inc. in 2006, eventually being acquired by Autodesk in 2009. Mike holds a BS in Mechanical Engineering from the Pennsylvania State University and a Masters in Mechanical Engineering from the University of Pittsburgh.*

## Optimization and the Design Process

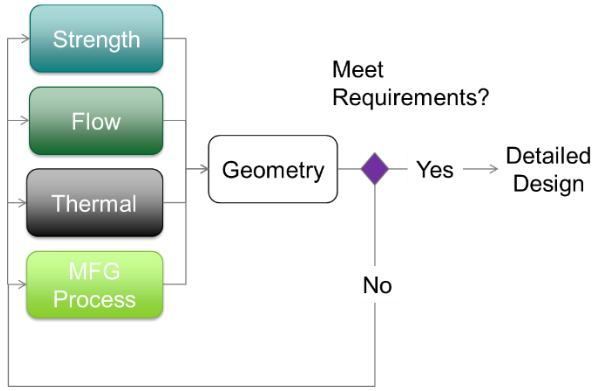
### What is Goal-Driven Design?

To define goal-driven design, we must first understand the more traditional design process. The steps of this process are generally accepted as design, build, test, iterate. In this process, a design is evaluated against performance requirements after the geometry has been established. Geometry definition typically starts with tribal knowledge and modification of similar designs where general dimensions and geometric features are adapted to meet the new design requirements. Once the design is finalized, prototypes are built, physical testing starts and traditional simulation methods are employed to validate results of physical testing.

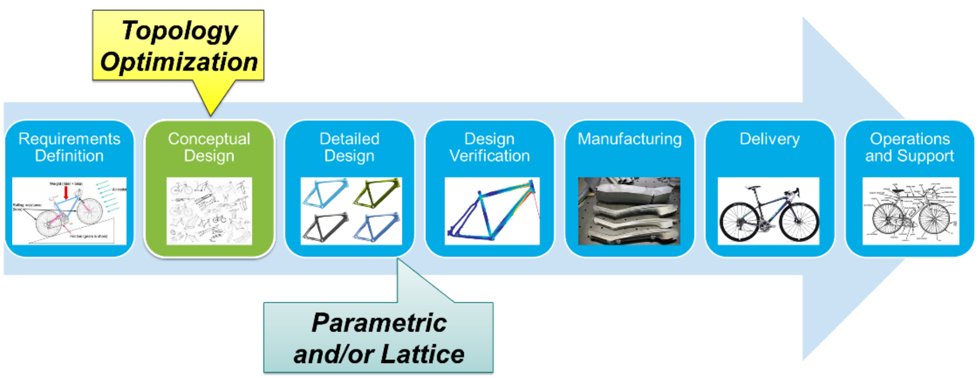



More recently, there has been a focus on implementing simulation earlier into the design process. The intent of this trend is to reduce the cost associated with building and testing physical prototypes. Simulating earlier in the design process helps predict if the design will meet performance requirements, and if necessary, allow for design changes to be made before the first prototype is built. In this scenario, the goal is not to replace prototypes or physical testing, but to reduce the number of iterations associated with redesign, prototyping and physical testing due to failure to meet performance requirements.

As technology continues to improve and market demands continue to change, the design process is evolving, such that the geometry creation process can start to be driven by the performance requirements, rather than simply being evaluated against these requirements. This technique is known as goal-driven design. Goal-driven design differs from the traditional “design, build, test, iterate” process in the sense that CAD is not just part of the documentation process, but is now supporting design exploration. Rather than modifying an existing design and leveraging tribal knowledge around how things were always done, a user can more easily start with a blank sheet of paper. Goal-driven design allows users to focus on design goals, manufacturing processes and performance requirements to support the geometry creation process, where the performance defines the geometry, more so than where the geometry defines the performance.



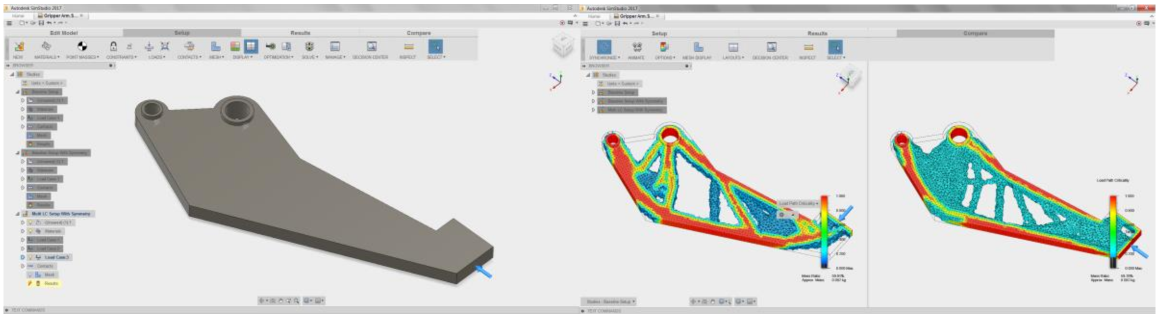

Goal-driven design is not a one size fits all process. There are multiple simulation and optimization technologies that support goal-driven design. Topology, parametric, lattice and evolutionary optimization technologies can all play a role in supporting the goal-driven design process. Each one of these techniques will come at various levels of complexity and fall in to various stages in the design process. Looking at the end to end product lifecycle, goal-driven design and the associated optimization strategies are well suited to support the early phases of conceptual and detailed design, as it focuses on using performance requirements to support design geometry creation.




## Optimization Strategies

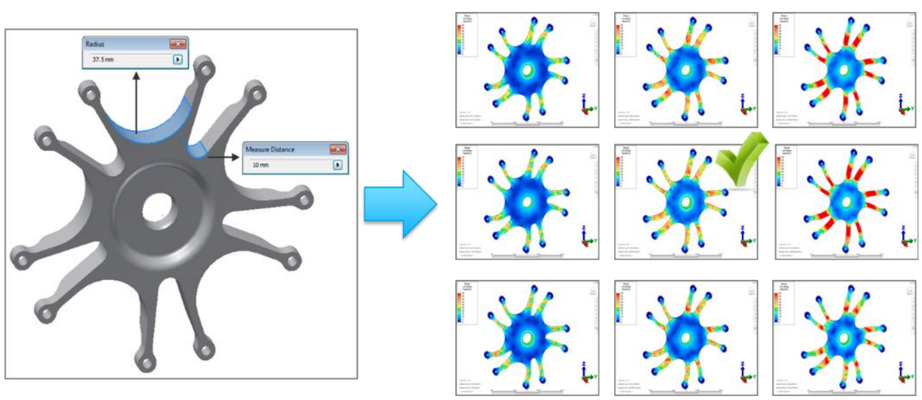
### Topology

Topology optimization requires a user to define an intended design space, loads, constraints and the desired performance targets. In this scenario, the analysis results will produce an optimized material outline or shape. Since topology optimization is generating a shape from a basic design space, it can be implemented much earlier in the design process, as the shape result can be used as a starting point for the design concept. In many cases, however, the shapes generated are organic or quite complex to manufacture using traditional methods. Additional analysis constraints can sometimes be used to overcome this situation, but in some scenarios, it is up to the user to translate the optimized shape recommendation into the nearest possible shape that can meet their manufacturing requirements. Today, Autodesk provides topology optimization functionality as a CAD-embedded solution, called Shape Generator, in Autodesk Inventor. Click here to learn more. In addition to this CAD-embedded solution, Autodesk has released a Technology Preview called Project Arro, where topology optimization is being offered in the standalone simulation platform, SimStudio. Click here to learn more.



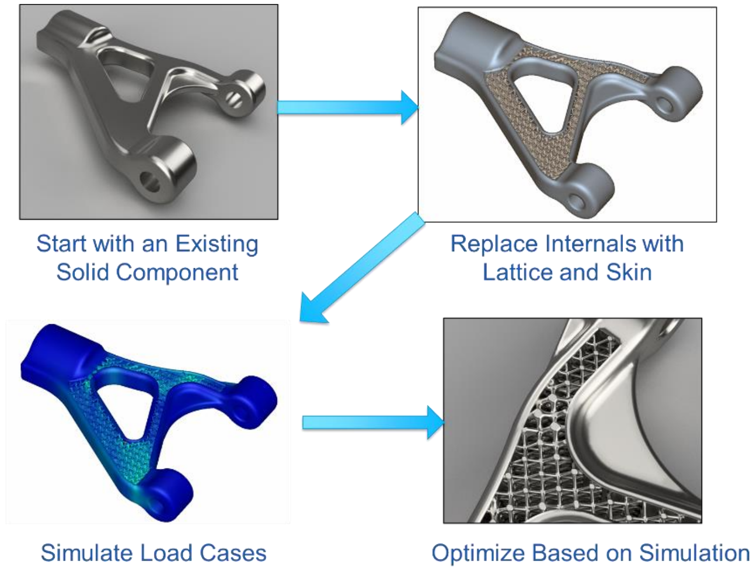
**Parametric**

Parametric optimization requires the user to define the specific geometric parameters from a design that will be varied as part of an optimization study under a given set of loads, boundary conditions and materials. Since the user is varying parameters of the design, the design must be fairly well developed to achieve a meaningful result. A challenge with this technique is that the user has to have tribal knowledge or general intuition as to which parameters to include in the optimization process that will yield the best results. It is possible, that based on the selected parameters, the optimization study will not yield the most optimum result for the geometry, if the most sensitive parameters were not included in the study. A user might think that a simple solution to this is to just include more or all of the parameters in a design, however, this might not be the ideal approach. As a parametric optimization analyzes all of the possible combinations of defined parameters, this could significantly increase the optimization study analysis time. This will also create additional results that the user will need to evaluate during their decision making process. Today, Autodesk provides parametric optimization study functionality in Autodesk Simulation Mechanical. Click here to learn more.

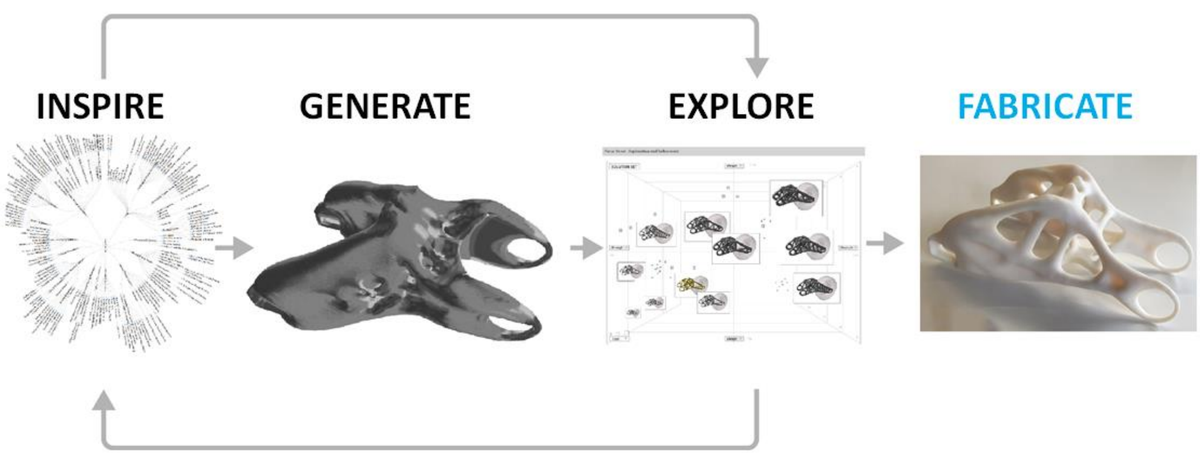



**Lattice**

Lattice optimization takes a similar approach to topology optimization however it focuses on the interior core of the design. The lattice optimization process starts off very similar to those processes already discussed in that the user must define materials, loads and boundary conditions. Different than the other techniques already discussed, the user is also required to define the internal material space regions that will be replaced with lattice structure that will undergo further optimization. In addition to defining this space, there are a number of lattice types that a user can choose from to define their interior geometry. Rather than optimizing the design's surface, lattice optimization will vary the internal structure to optimize performance and reduce weight. Lattice optimization also goes one step beyond simple optimization for performance, optimizing geometry and performance based on manufacturability with additive manufacturing processes. Today, Autodesk provides lattice optimization technology as part of Autodesk Within. Click here to learn more.




**Evolutionary**
Evolutionary design and optimization is yet another class of technology that starts to combine components of the three approaches that we have discussed so far. The intent of evolutionary optimization is to help users explore an even broader design space and have software play an active role in the invention of the design form. Evolutionary design and optimization is in an active research phase at Autodesk, known as Project Dreamcatcher. Click here to learn more.



## Topology Optimization with Project Arro


**Project Arro Overview**
Project Arro is a technology preview for an emerging simulation product called SimStudio. It is built on a geometry foundation that allows users access to modeling, simplification and geometry prep tools. On this foundation, we have added simulation pre and post processing capabilities to support linear and nonlinear stress analysis capabilities, topology optimization and explicit dynamics.

**Topology Optimization Workflow Overview**

Step 1: Prepare the Geometry

SimStudio will allow users to import models from various CAD platforms, or create geometry directly inside the simulation environment using direct, parametric of freeform modeling tools. SimStudio also has powerful simplification tools to recognize and remove unnecessary features from the geometry.

Step 2: Define Simulation Parameters

As part of the setup process, users will define a material type, loads and constraints and mesh settings. It is important to pay attention to mesh settings, as multiple elements are required through the thickness to ensure there is material to remove. Further, users have the ability to define multiple load cases against a given geometry. In the case of multiple load cases, the analysis will evaluate each load case and arrive at a geometry that is suitable to meet all load case requirements.

Step 3: Define Optimization Parameters

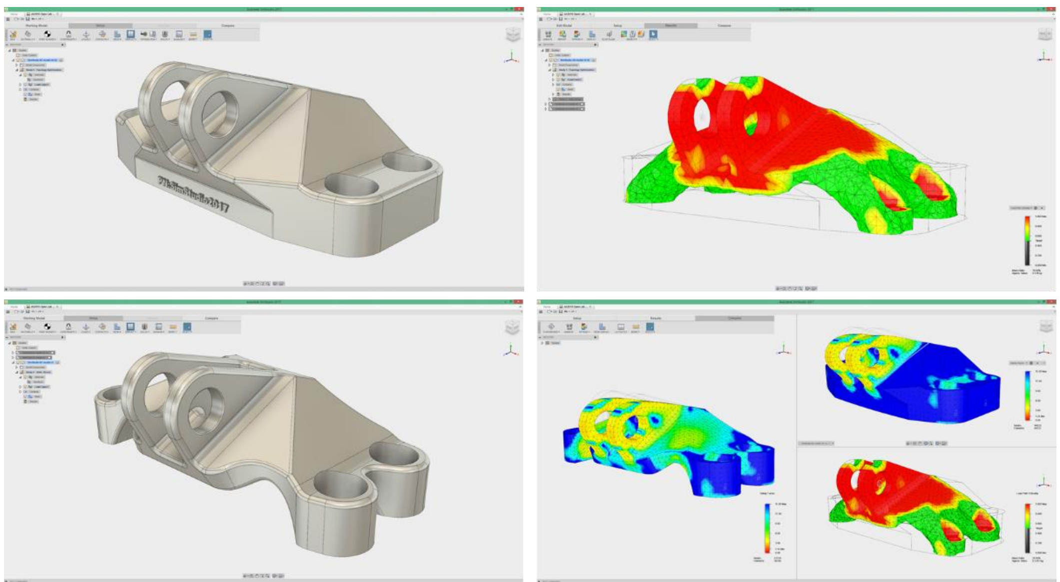
Once the simulation parameters are defined, users will define optimization parameters. These parameters consist of preservation regions, constraints, objectives and possible planes of symmetry. Currently, SimStudio offers users the ability to maximize stiffness, while minimizing the mass.

Step 4: Review Results

When an analysis completes, SimStudio presents users with a recommended topology shape based on the specific mass target. Users can also use the handles on the legend to look at recommended shapes based on various mass ratios and approximate mass values. The model will be shaded based on the Load Path Criticality.

Step 5: Update Design

With proposed topology shape information, it is now time to consider design modification. As noted in Step 1, SimStudio provided powerful modeling tools for geometry creation and modification. Currently, a user can create new geometry or create a new working model and modify the existing geometry to represent the recommended shape. Once model updates are completed, they can be used for subsequent simulations to validate the final shape.



**Access to Project Arro**

Project Arro is available as a technology preview on Autodesk Labs. The tech preview is updated on a monthly basis with new features, workflow enhancements and software fixes. Click here to request access to Project Arro. We look forward to your participation and feedback.