CLASS ID: CP500001

A Practical Guide for Generative Design in Product and Industrial Design

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Learning Objectives

- Discover best practices for setting up and running a generative design study.
- Learn how to use obstacles and preserved geometry to obtain results that align with specific design intent.
- Learn how to set up forces, constraints, and other technical details of a study in a practical way.
- Learn how to combine generative design geometry with components modeled directly in Fusion 360.

Description

Generative design is a powerful tool that requires technical knowledge that doesn't necessarily align with how designers work. This class will explore four key strategies for integrating generative design into product and industrial design: 1) Understanding best practices for setting up a generative design study, and determining how much modeling work is needed prior to running the study. 2) Obtaining outcomes that align with the design's original vision. It's common to see designers grow frustrated as they run several studies that create shapes that are unusable as actual components of a product. 3) Understanding in practical terms details related to forces, constraints, and other technical information that is not commonly used in product design, and that might affect the effectiveness of the generative outcomes. 4) Understanding how to best merge generative design geometry with other components that have been modeled directly in Fusion 360 software.

Speaker

Alex explores design, technology, sustainability and emotional attachment as means to elevate quality of life. He is Professor and Graduate Director of Industrial Design at Rochester Institute of Technology, and Research Fellow Emeritus at Autodesk. At RIT, Alex leads a top-ranking program focused in interdisciplinary collaboration, accessible technology and applied design research. Alex and his students have partnered with Autodesk, AT&T, Colgate-Palmolive, General Electric, Makerbot, Stryker, Staples and Unilever, in projects covering digital fabrication, sustainable behaviors, learning futures, generative design, and everyday living. Alex holds a MFA from University of Notre Dame and a BID from Universidad Rafael Landivar.

The value of Generative Design

Generative design develops complex forms and structures similar to those found in nature, taking advantage of automated tasks and high-scale computing power. This approach benefits designers in the creation systems that are efficient, resilient and visually engaging. These systems follow specific rules for form generation and meet clear design goals in terms of shape, strength, mass, and other physical attributes.

From a designer's point of view, most of the approaches fall into two categories: by subtraction and addition. In a subtractive process, objects are analyzed based on specific targets for strength, mass or similar attributes, and any sections that are unnecesary to satisfy them are removed. An additive approach predefines design goals and constraints for a given problem and generates large number of iterations of potential solutions that meet such goals. Subtractive processes have relatively small learning curves but they tend to offer only incremental improvements over current solutions. Additive processes provide more benefits and flexibility for form generation and automation of processes but their steep learning curve makes them hard to use, discouraging designers without adequate knowledge on mathematics and programming.

While the use of any of these two approaches provides great potential for design development, it is common for designers to pick one of the two approaches early in their development process and not make an effort to include the other approach along the way. The combination of subractive and additive methods, however, can lead to solutions that are more effective and cohesive. This paper discusses an integrated method based on iterative design processes where designers refine their concepts multiple times, achieving higher levels of success. This integrated, iterative process puts designers at the center of the process, providing tools with varied benefits and levels of complexity, that maximize automation and computational processing power.

Autodesk's Generative Design workspace

Autodesk offers a generative design tools within Fusion 360, which provides excellent results for creating novel designs:

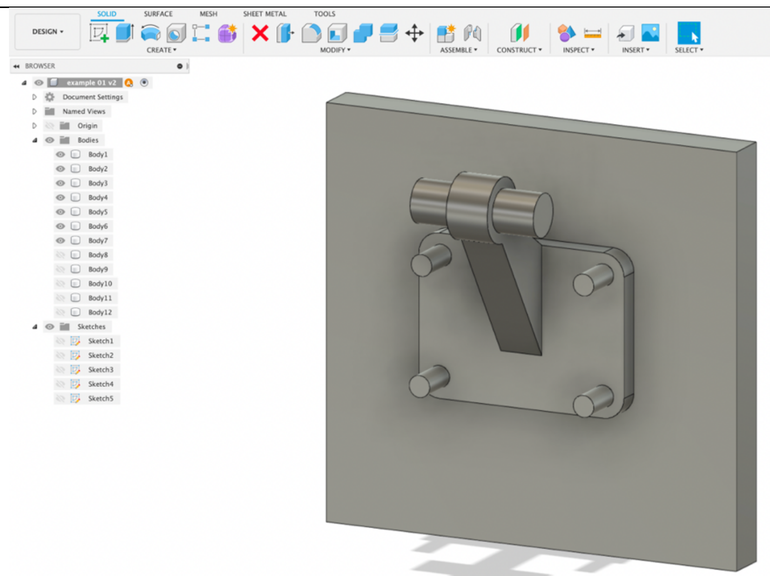
> **Generative design is a design exploration process tool. It allows designers and engineers to input design goals into the generative design software, along with parameters such as performance or spatial requirements, materials, manufacturing methods, and cost constraints. The software explores all the possible permutations of a solution, quickly generating design alternatives. It tests and learns from each iteration what works and what doesn't. (https://www.autodesk.com/solutions/generative-design).**

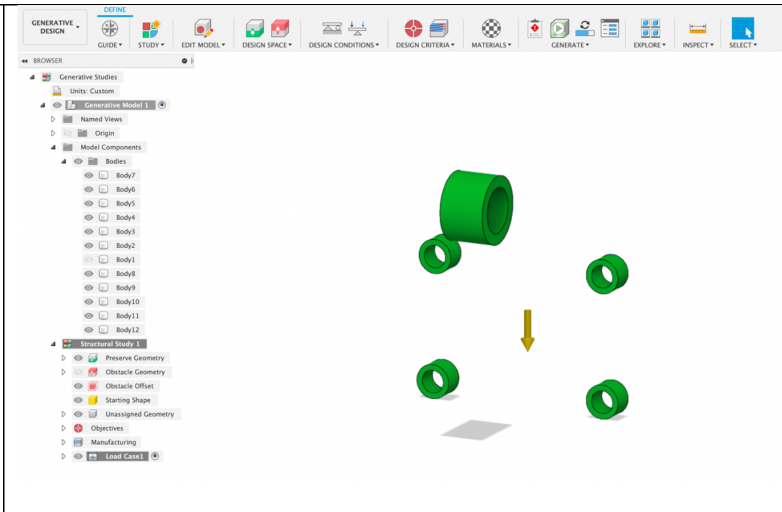
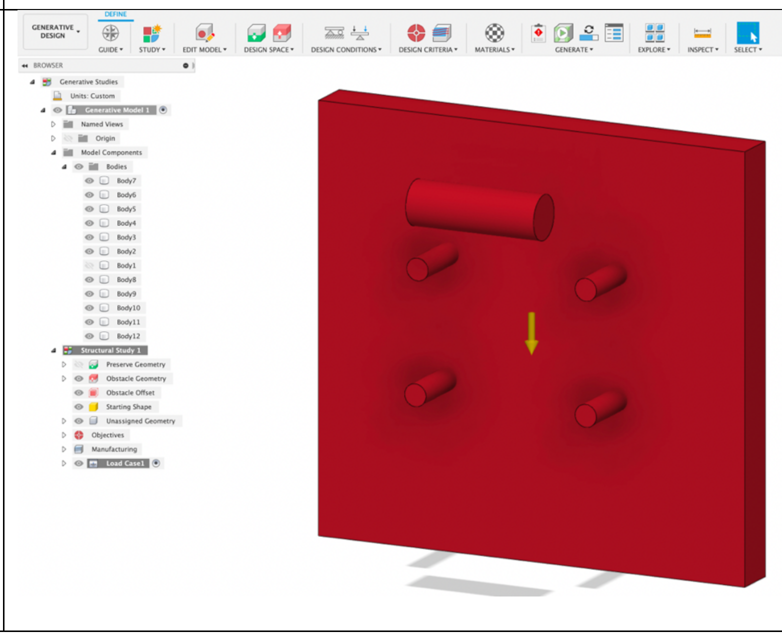
While this tool is powerful and effective, it is intented primarily for engineering. Because of this, many of its features and results involve a high degree of technical details. Designers that want to use generative design, can feel overwhelmed and discouraged by the structure of the tool. This class takes key features and workflows within generative design and reframes them for a design audience. The class will illustrate the power of generative design to create novel solutions as well as to use it as a tool for exploration, refinement and inspiration.

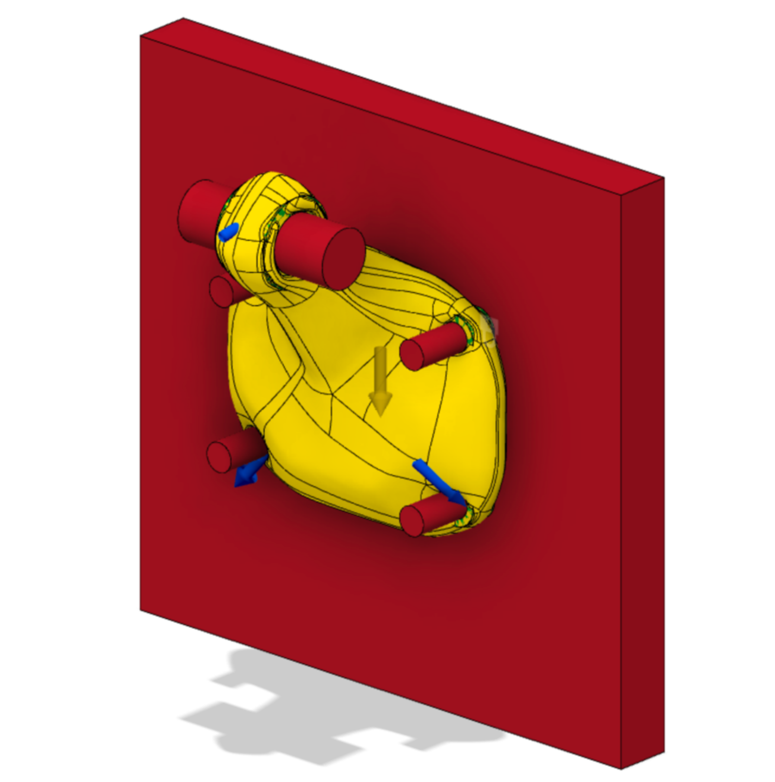
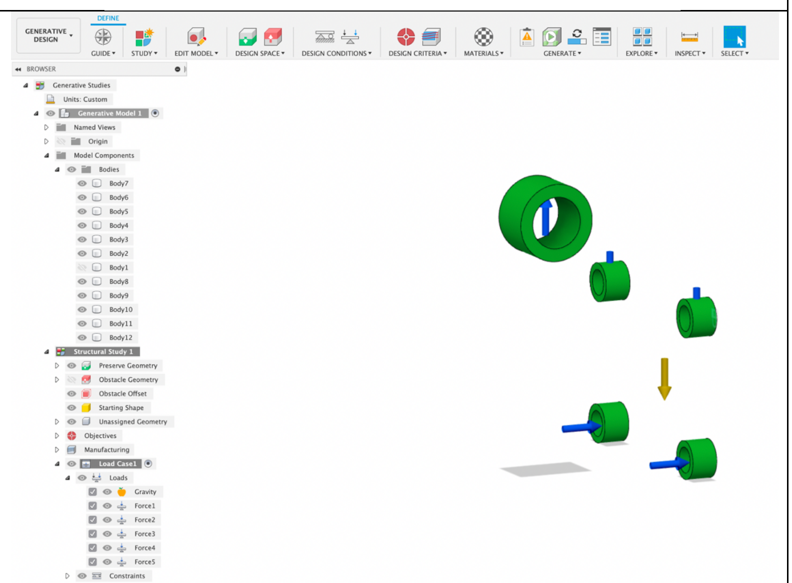
A series of step-by-step workflows described below include:

- Generative Design's workflow
- Using Generative Design as an iterative process
- A quick guide for inputing force and constraint values into a GD study
- Exporting a GD study as a Fusion 360 model
- Common methods for refining GD geometry
- Examples of how GD can be optimized for easier fabrication.

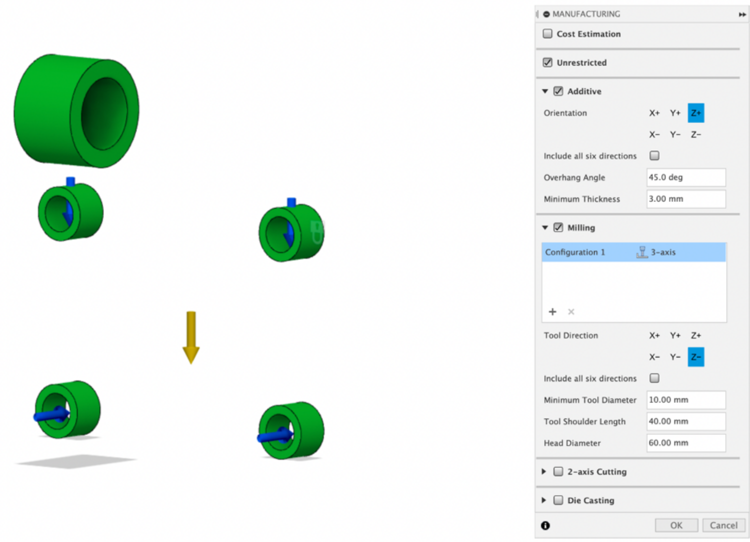
Generative Design's general workflow

In the design/model workspace, create your design. This helps to figure out the components of the design. This will provide information on size, dimensions and additional information for setting up the GD study.	

In the Generative Design workspace, create a new study The first step is to assign the preserve geometry. This is typically where the GD outcome will make contact with the other parts of the design and where the forces will act on the design.	
Now set obstacle geometry. This is used to prevent GD from creating geometry in certain areas. Those areas can be existing component that cannot have interferences, or simply areas that the designer wants to maintain open.	

A starting shape can also be included (but it's not necessary to run the study). This can be used when a general shape of the outcome is already defined. Starting shapes need to be in contact with all preserve geometries.	
Now apply forces and constraints. Forces put pressure on the design. They include weights, pulling/pushing forces, etc. Constraints are used to set fixed elements of the design and to ground it in place.	

<table>
<tr>
<td>Add manufacturing constraints.

These are very useful to obtain outcomes that fall within specific limits, such as manufacturing processes, cost, and materials.</td>
<td>
</td>
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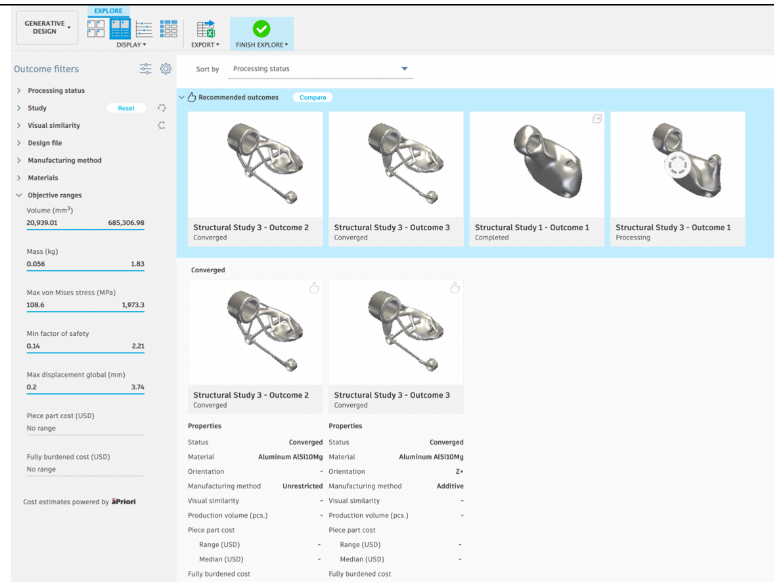
<tr>
<td>Generate study

When all the goals and parameters have been use, use “Generate” to run a GD study.

The study will run in the cloud and will show various outcomes as they are completed.</td>
<td>
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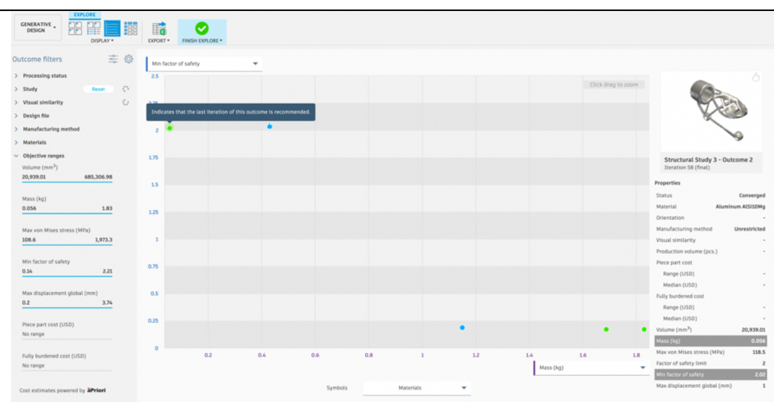
<tr>
<td>Select best option and export

As the results are generated, it is possible to compare them according to several criteria, in order to identify the outcomes that work best for the design.

Any outcome can be exported as a Fusion 360 model or as a mesh.</td>
<td></td>
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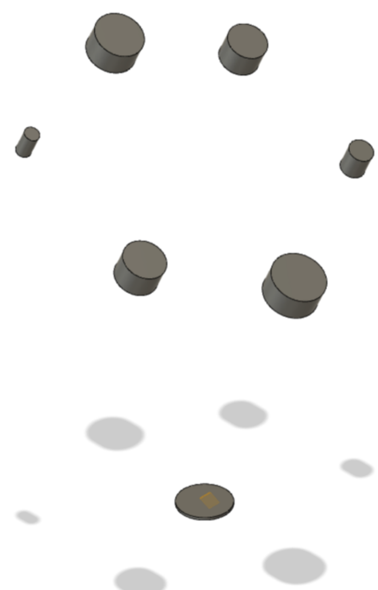
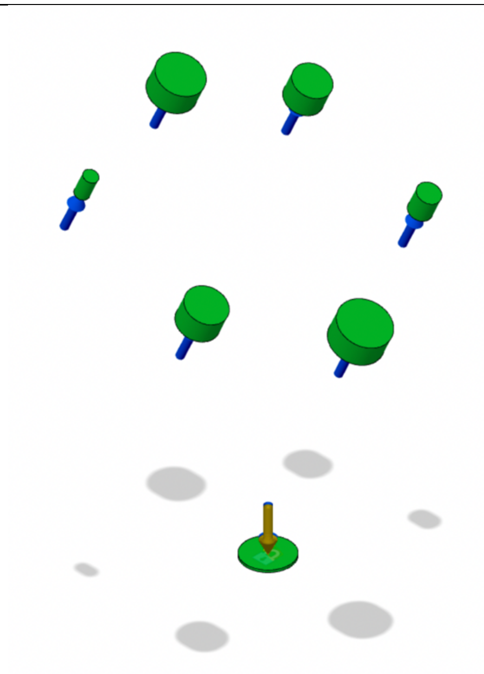
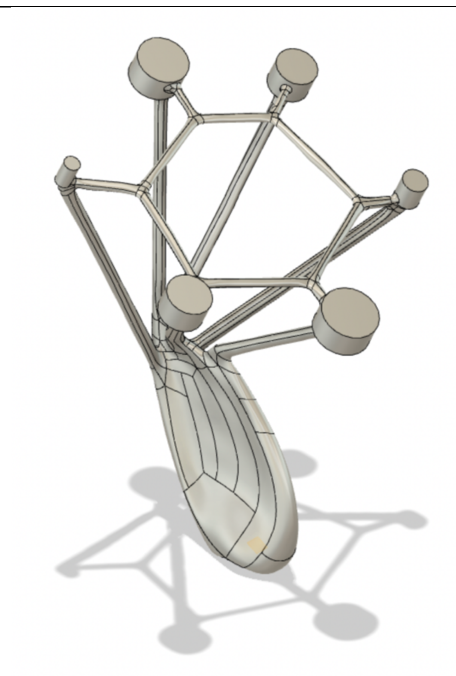
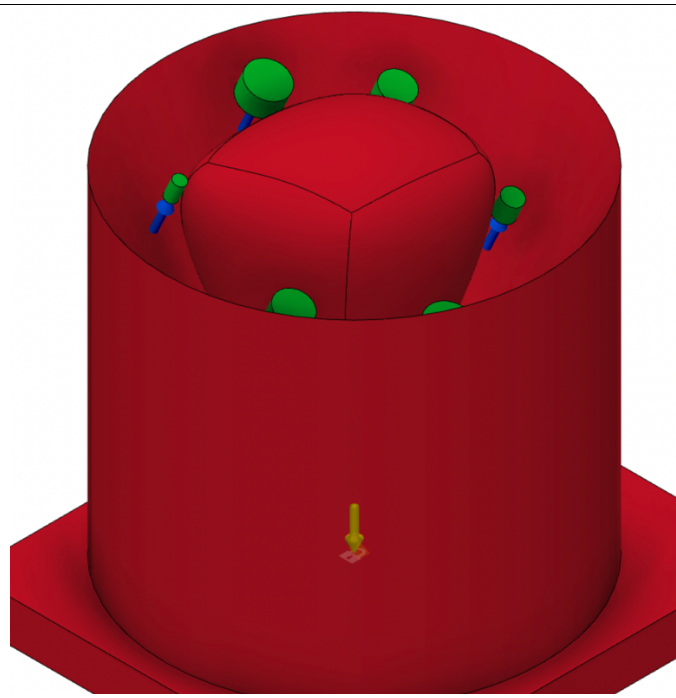
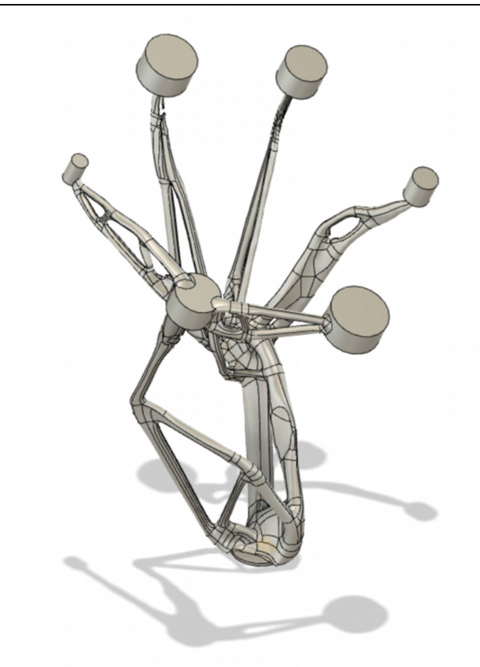
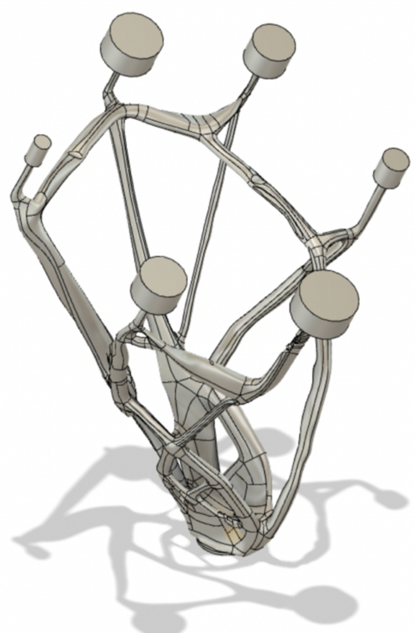
Using Generative Design as an Iterative process

- It's helpful to run a simulation with no obstacles first, in order to get a general sense of how GD creates the study without restrictions.
- From there, obstacles can be added a few at a time, so that the study is not over constrained, limiting the form exploration that GD can provide.
- As this process goes through several iterations, designers can be inspired and guided by the different results that GD provides.

The exploration starts with identifying the key points of the structure. These points typically align with support points and joints in a design. In this case, the exploration is similar to a tree: a base on the ground and six points positioned higher.	

Force loads are assigned to each of the bodies. For the first study, no obstacles are included. This will show what GD creates when having no limitations.	
The result shows great potential. It would be nice if the base was thinner and the top portion didn't have that many connections.	

A second study introduces obstacles. Three obstacles are used: -a box at the bottom so that no geometry grows down. -an inner body that prevents too many top sections in the middle -an outer cylinder so that the outcome is not too wide.	
The second study shows a more interesting and balanced shape. -an unexpected detail is that now there is geometry growing above the upper bodies.	

A box is placed right above the upper bodies and used as obstacle.	
A third study gets even closer to the desired outcome. It also shows that if geometry is not allowed above the upped bodies, maybe the connections in the middle are essential to meet the structural requirements of the design.	

Understanding forces and constraints

Generative Design is based on technical principles involving forces, magnitudes, constraints, and similar factors. While these principles are common in many areas of engineering, they are not necessarily covered in other disciplines such as Industrial Design. Because of this, many people that uses Generative Design can often feel lost and overwhelmed when having to enter force values for a study. In many situations, the values used end up not being correct, and while a GD study will be generated, it won't necessarily provide the structure or performance needed for its application.
In order to understand better how forces work for GD studies, we can focus in this formula:

$$\mathbf{f = ma}$$

force (N) = mass (kg) x acceleration (m/s^2)

In this case, force equals mass multiplied by acceleration, and the values are set in Newtons, kilograms and meters/seconds2, respectively. To put this in general terms, if a body needs to support a weight of 250 pounds, for example, the force value that should be used in a GD study is about 1117 Newtons:

250lb (114kg)
f= ma
f= 114kg x 9.8m/s^2
f= 1117N

As another point of reference, there is a difference between pounds and pounds force. Pound as a unit refers to the mass of an object, but in order to use it as a force, we need to add whatever value sets it in motion. So in the case of 250 pounds, its value affected by gravity would translate to 2450 lbf (250lb x 9.8 m/s^2).

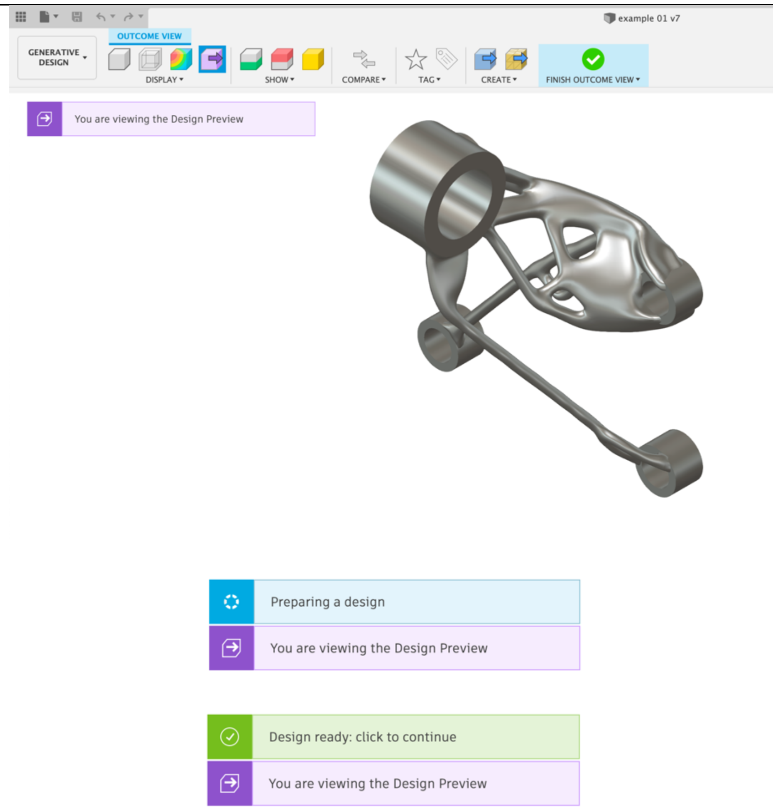
Below is a list of common forces that are used in everyday applications. These values can be helpful to determine the forces that can be included in a GD study. Setting up accurate values can be a complex process and needs to be performed by professionals. This guide does not intent to replace the job of an engineer but rather to give designers and other users a general idea of the force values behind common situations.

Common forces for everyday applications

250lb person standing	1117N
Opening door (residential)	22N
Opening door (commercial)	66N
Bicycle pedaling	700N
Punch (low force)	2500N
10lb object's freefall (4ft)	530N[1]

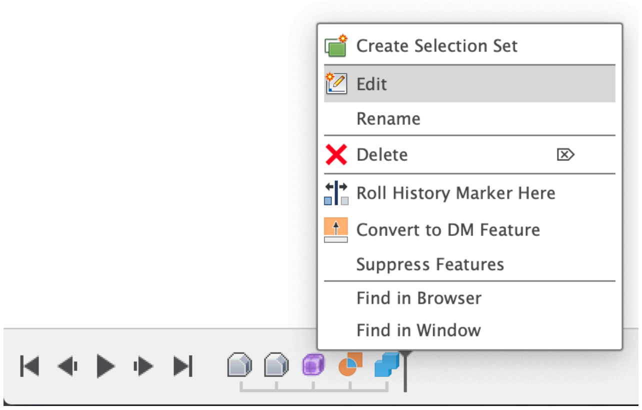
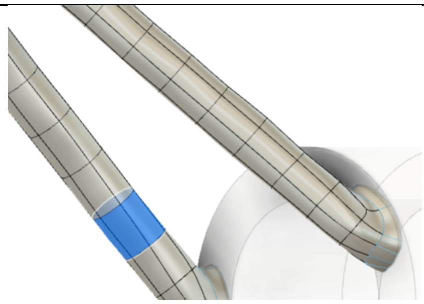
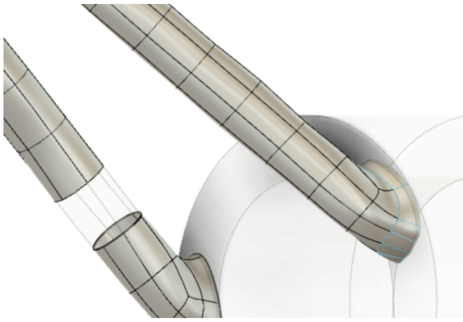
[1] Free fall adds acceleration to the calculation, which was determined using this calculator: http://hyperphysics.phy-astr.gsu.edu/hbase/flobi.html

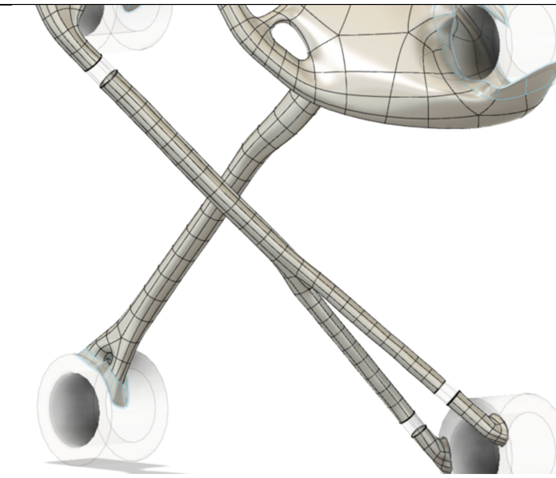
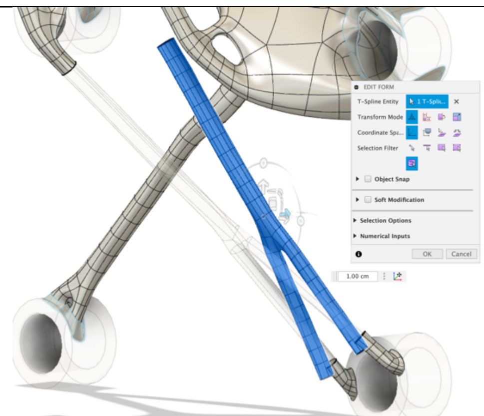
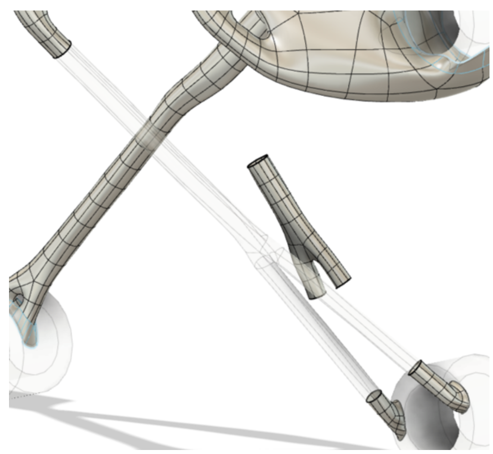
Exporting a Generative Design study

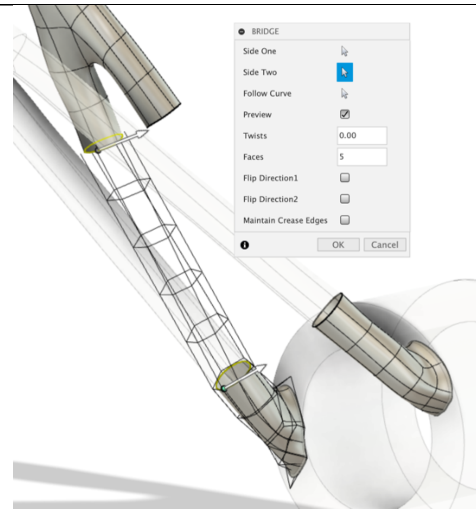
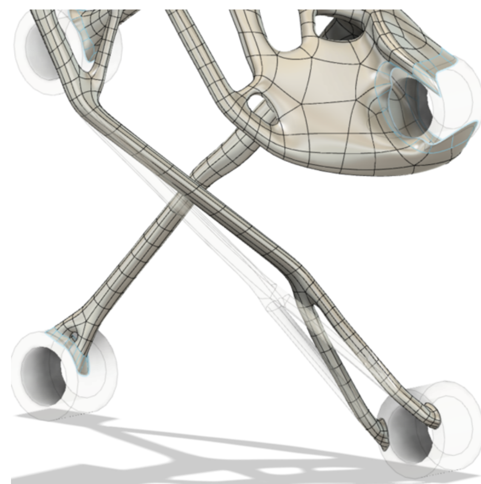
1- Double-click on any outcome thumbnail to access it. 2- Go to the “Create” tab and select “design” or “mesh” 3- You will see a blue message: “preparing design” 4- When ready, you’ll see a green message: “Design ready. Click to continue.” This will open the outcome as a new part that can be saved and edited. NOTE: “Create Design from Outcome” produces a model more versatile than “mesh.” It creates an editable Fusion 360 file that includes B-rep model as well as the T-Splines boby that resulted from the GD simulation.	

Refine the geometry of a GD study:

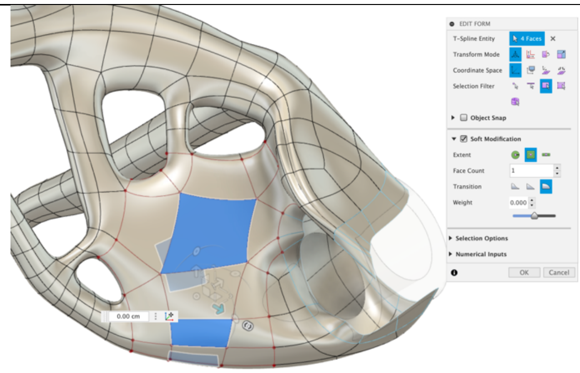
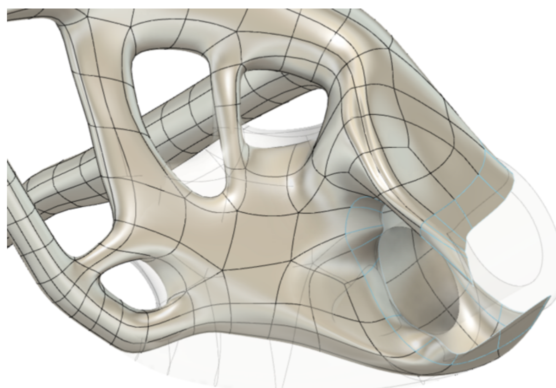
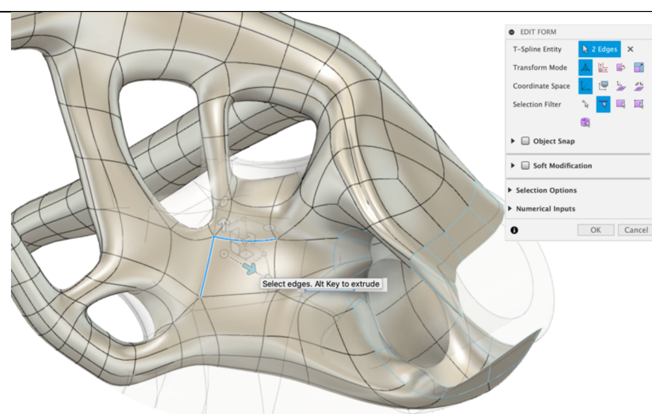
Reposition and rebuild sections

Open the part and edit	Open the newly created part. In the bottom timeline, right-click on the purple "organic" icon and select "edit" You will enter the "form" environment, where you can edit the form.	
Remove end sections	Select one end of the section you want to reposition. Use the "del" key to delete.	 

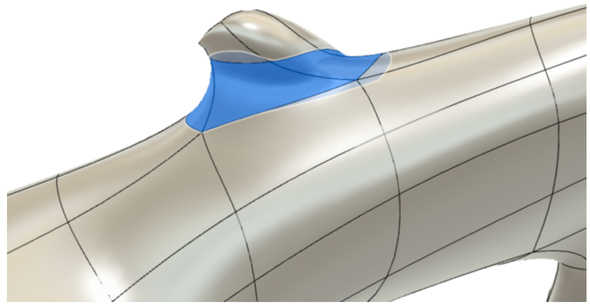
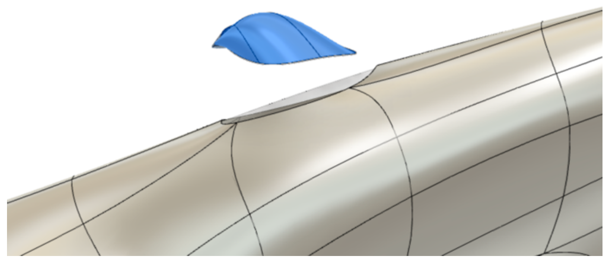
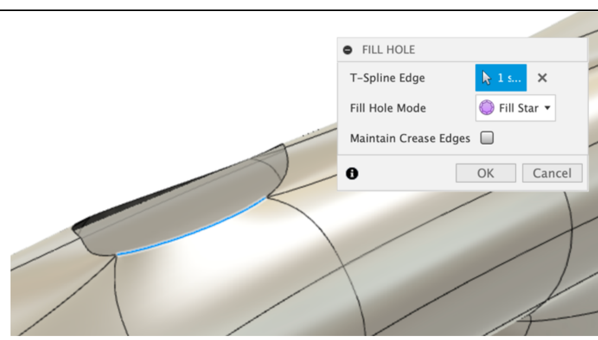
Remove end sections	Repeat the process for the other ends of the section to be removed.	
Reposition desired section	Go to Modify > Edit form and move/scale the section as needed. Select any extra faces that need to be removed and press the “del” key.	 

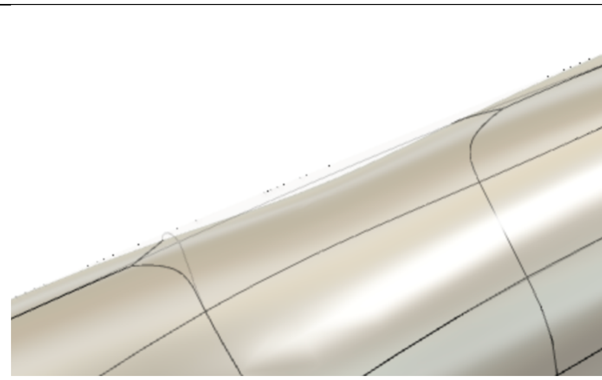
Reconnect the sections	Go to Modify > Bridge. Select the whole edge of the end sections to be reconnected. Repeat the process for the remaining sections. Use Edit Form to refine the new connections.	 

Move and Scale a section

Select region to scale	Go to Modify > Edit Form. Set selection filter to "faces" Check "Soft Modification" and set Extent to "Face Count" Select faces and Adjust "face count" in order to highlight the desired region. Hold the "command" key to select multiple faces. Use the orbit to move/scale as needed.	 
Refine specific sections	Go to Modify > Edit Form. Set selection filter to faces, edges, vertices, etc., as needed. Unheck "Soft Modification" Select geometry and use the orbit to move/scale as needed.	

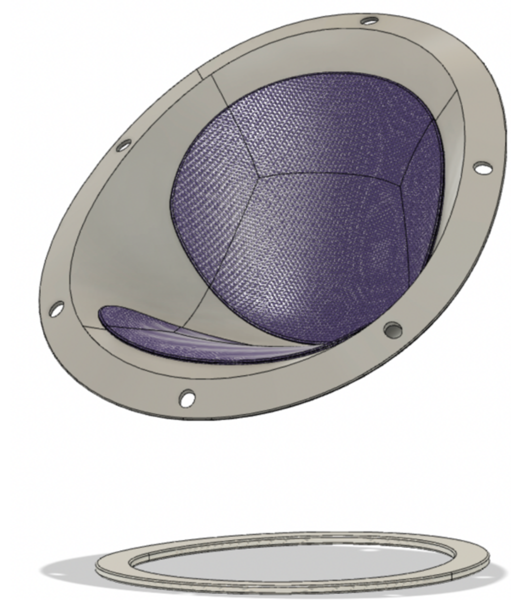
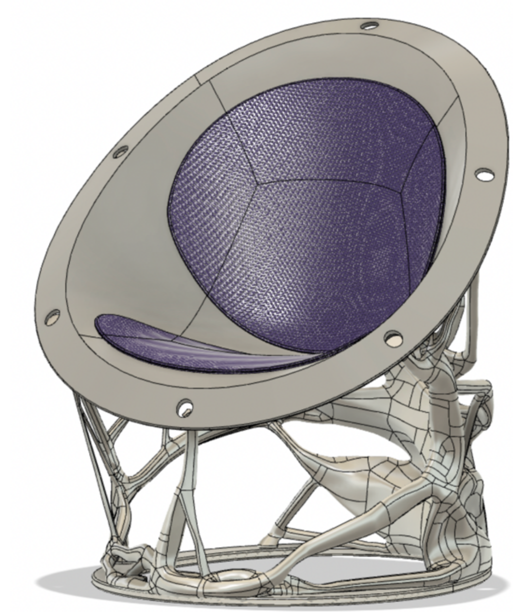
Remove unwanted bumps

Remove unwanted section	Select faces to isolate bump from the main body. Hit the “del” key to delete them. Select the remaining bump and delete it.	 
Fill hole	Go to Modify > Fill Hole Select one of the edges of the option. Scroll through the fill hole types to see which one produces the best geometry.	

Optimizing GD studies for Fabrication

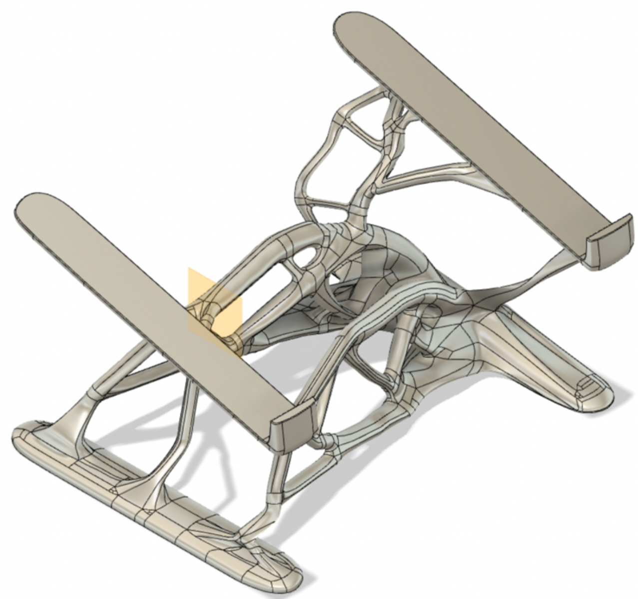
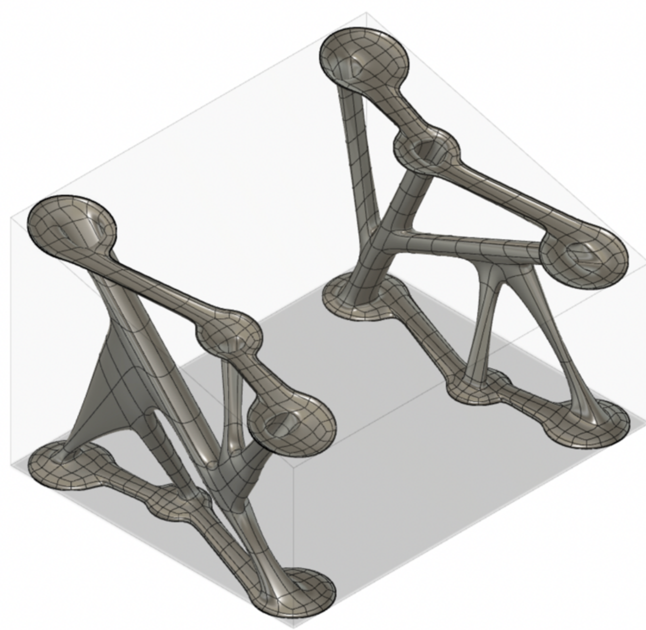
Example 1: Lounge chair

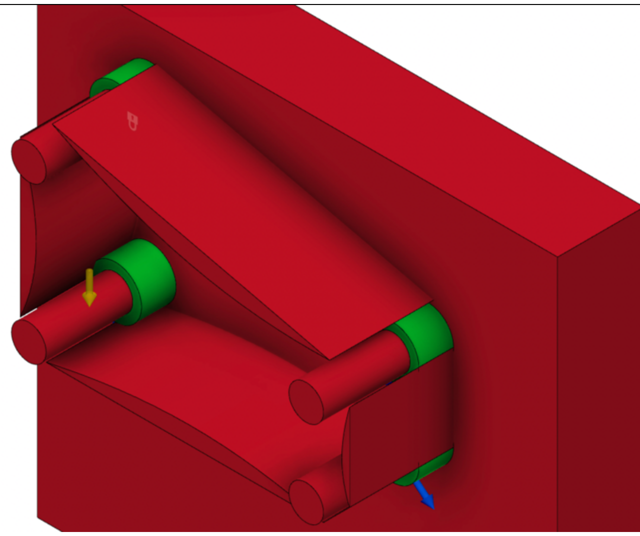
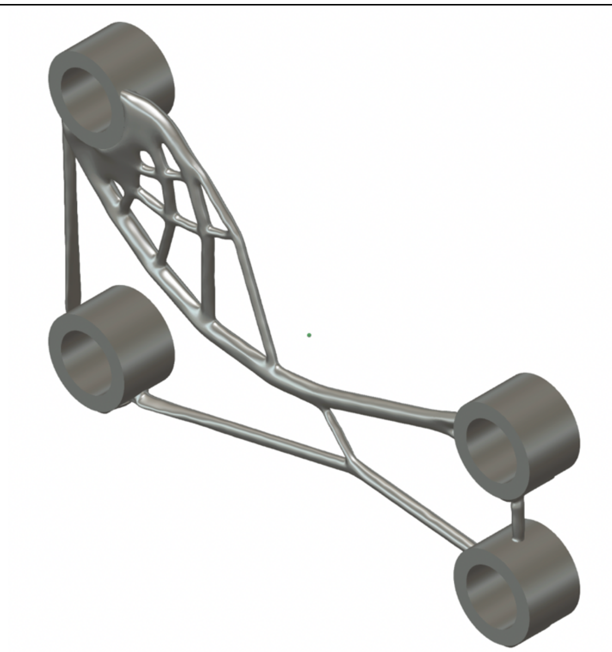
This chair will use a generative design frame to connect the base to the upper section.	
A first study is generated to include all connection points. The result is interesting as a sculptural form but it would be extremely hard and expensive to produce. It woud also be hard to find a facility that could handle a model of this size.	

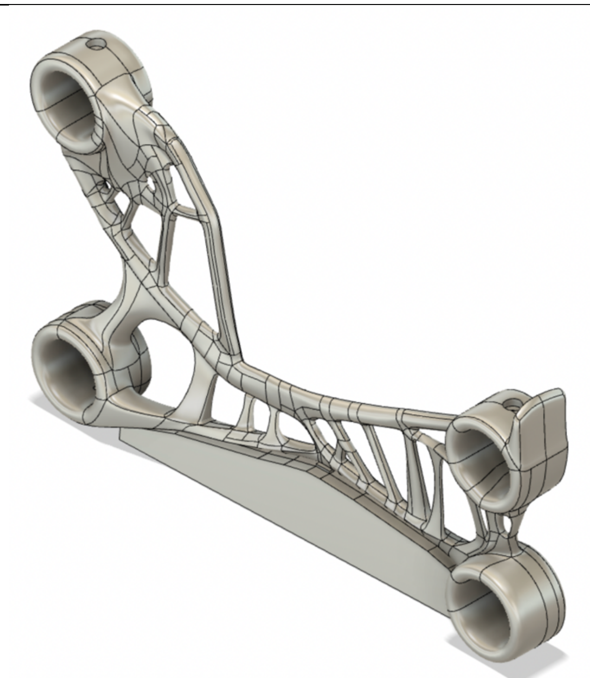
A new approach is used. The frame is broken into four sections. A GD study is generated for each of the sections. This results in a frame that is more feasible to produce in terms of manufacturing, cost, and scale.	

The end result maintains the dramatic effect of the generative design frame and also provides a more practical solution.

Example 2: Laptop stand

A laptop stand wants to integrate generative design into its frame. The fabrication method envisioned is 3D printing. The initial version shows a very dramatic shape. But from a fabrication standpoint, this shape will be very hard and expensive to produce.	
A quick form study using T-Splines geometry shows a more practical direction, where the GD frame can be used on the side ends only.	

A GD study is setup, using as preserve geometry four cylinders that will connect wooden dowels together. Obstacle geometry is added to make sure that the study grows in a fairly compact space.	
The GD outcome looks very promising. Two issues might need to be addressed: -Some of the sections look to thin and might break easily if the parts are 3D printed. -Several sections create long horizontal sections with little support underneath. If this geometry is 3D printed, it will require support material, which will make the part hard to clean up.	

The part is imported into Fusion 360 and is edited. -The overall width is increased, so improve its strength. -Vertical sections are added underneath the horizontal sections. While this is not necessary to hold the weight of a laptop, it actually helps to support the frame while printing so that no support material is needed.	

The final result highlights the use of generative design while keeping the overall design easy to fabricate and also assemble/disassemble.