THE NEXT GENERATION OF DESIGN

HOW NEW MODELING TECHNOLOGIES CAN BOOST DESIGN PRODUCTIVITY IN SMALL AND MID-SIZE COMPANIES

LIFECYCLE INSIGHTS

PLUGGING ENGINEERING PRODUCTIVITY LOSSES

Time is at a premium for today's engineers in small and mid-sized companies. Quite literally, there is simply too much to do. You bear the full weight of design responsibilities. You have to work with customers, suppliers, and partners. You must spend time on the manufacturing floor to identify and resolve outstanding product issues. The list goes on and on. When an engineer sits down at a desk, they *must* be highly productive.

One of an engineer's primary responsibilities is to build the digital geometry of their designs. It lets them check form and fit. It is essential for analysis. It helps generate the toolpaths that drive CNC machinery. It is used to develop drawings. Design geometry is the spring from which many downstream activities flow.

Productivity in the production of design geometry has recently increased dramatically. Parametric Modeling lets engineers meticulously capture design intent with dimensionally controlled features, enabling faster and intelligent changes. Direct Modeling lets engineers push, pull, and drag design geometry quickly and easily. Both modeling approaches have served engineers well.

Unfortunately, the productivity of some design activities has not advanced. Efficient support of reverse engineering, where existing components are digitally scanned and saved as mesh geometry, is still sorely lacking. Generative Design, which leverages methodologies for computer software to generate design alternatives, outputs mesh geometry. 3D Printing activities, which likewise rely on mesh geometry, also need modification. All three activities utilize faceted data, yet Parametric and Direct Modeling do not work with this kind of geometry.

Nevertheless, the technologies needed to work with mesh geometry do exist. Facet Modeling lets engineers fine tune the quality of the mesh and add or remove material. Until lately, the primary problem was that the combination of Parametric, Direct, and Facet Modeling had not yet been combined into a single Computer Aided Design application. Because of this, engineers had to move geometry back and forth between these separate software tools. This resulted in translation errors and required users to learn multiple application interfaces. As such, these activities required laborious investments in time, and engineer's productivity dropped.

Fortunately, new solutions that address this shortfall are emerging. Some CAD applications have now integrated Parametric, Direct, and Facet Modeling into a single environment. These offerings promise to increase productivity for engineers in small and mid-sized companies.

Exploring these topics at greater depth is the purpose of this eBook. Here, you will find more detail on the current challenges of engineers in small and mid-sized companies, the broader range of design activities that need support, traditional solutions and their drawbacks, as well as progressive solutions and their advantages.

Today's engineers can ill afford productivity losses. CAD applications that offer integrated Parametric, Direct, and Facet Modeling capabilities offer real promise to regain that capacity.

TOO MANY RESPONSIBILITIES, TOO LITTLE TIME

Practically every member of a small or mid-sized company must wear many hats and undertake a wide range of responsibilities. The engineers in these companies are no exception.

THE DO-EVERYTHING ENGINEER

In larger companies, many engineers become highly specialized in certain aspects of the design and development process. For instance, an analyst might do little but run simulations all day, or an engineer might be dedicated solely to testing. You could see a group of engineers who only develop concepts for new products. Yet another engineer might manage suppliers' designs and their integration into the development process. These engineers are often deeply skilled and dedicated specialists with a well-defined subset of design responsibilities.

Engineers in small and mid-sized companies don't have that luxury. Because there are fewer of them, they must do it all. This not only means they have a broad range of responsibilities, but their daily schedule can vary widely. One day, they might remain at their desk doing design work, while on the next they're out inspecting a supplier's design. The day after that, they might be running a simulation and then getting ready for a physical test. These engineers are multi-skilled generalists who must undertake the whole spectrum of design responsibilities.

Because engineers at smaller companies must do it all, they are the ones who use the various software tools needed to complete those tasks. Therefore, they are the ones developing new designs and configuring old ones with Parametric Modeling, modifying legacy designs with Direct Modeling, and manipulating mesh geometry with Facet Modeling.

With their schedule so full, these engineers can ill afford the time it takes to learn and relearn specialty applications. CAD software should be an enabler for them, not a roadblock, so do-everything engineers are best served with a single tool that supports all of their activities.

CONSOLIDATING IT RESPONSIBILITIES

Another reality of engineering in small to mid-sized companies is the relative independence of IT. In large companies, a centralized group of managers is often responsible for installing, updating, and maintaining software applications like CAD. In smaller companies, engineers must take care of this, themselves.

Given their workload, time spent installing and updating software comes at the expense of time spent designing and developing products. While rationalizing software applications is often an initiative for bigger companies, engineers at smaller companies benefit the most from such efforts. Using one technology to do the work of two or three others is a win for engineers, if for no other reason than to avoid the IT management of more software applications. IT consolidation for these engineers is a good thing.

DESIGN SCENARIOS DEPENDENT ON MESH GEOMETRY

Engineering a product can include a lot of new development where design uses Parametric Modeling. Furthermore, many companies are trying to increase their design reuse where Direct Modeling is heavily employed. Finally, a third category of mesh geometry-dependent work leverages Facet Modeling. This section covers the scenarios where working with mesh geometry is required.

REVERSE ENGINEERING

One of the oldest practices in development, Reverse Engineering is the process of extracting design geometry from an existing physical object or product. The purpose could be to develop a new design that improves upon the existing component, or to develop a new component that fits alongside the existing one. In any case, Reverse Engineering is essential when there are no design representations for the existing product. For instance, if the item's manufacturer no longer exists, or if the product was developed before the digital age, designs may not be available. Regardless of why Reverse Engineering is needed, the organization must start with the existing product and work backwards, developing designs from the object.

Reverse Engineering such components can involve studies, physical testing, and disassembly of the existing product to understand how it functions. Ultimately, some digital 3D representation needs to be produced for traditional downstream development activities such as procurement, manufacturing, quality, and more. Producing that digital representation frequently involves 3D scanning.

When scanning a physical item, individual sensors take thousands of measurements of the item and produce a point cloud. Modeling software then creates planes between these points, and the result is mesh geometry.

There are many permutations involved with Reverse Engineering depending on the ultimate objective. These objectives include the following:

- **Scan-to-Surface:** Here, the engineer wants to scan the physical item and develop a digital 3D surface model, perhaps to integrate it into a design created using Parametric and Direct Modeling.
- **Scan-to-Print:** In this scenario, the engineer wants to scan the physical item and then use 3D printing to produce a physical copy. Interestingly, this path skips the traditional modeling approach completely.
- **Scan-to-Toolpath:** With this use case, the engineer wants to scan the physical item and reproduce it using traditional machining methods.

Note that in each of these cases, modifications may be required. An engineer may scan the physical item and need to add holes, ribs, or other kinds of geometry necessary for mounting or attachment. In such scenarios, working with mesh geometry in traditional CAD applications becomes disjointed or broken because these applications do not offer the right combination of capabilities.

GENERATIVE DESIGN

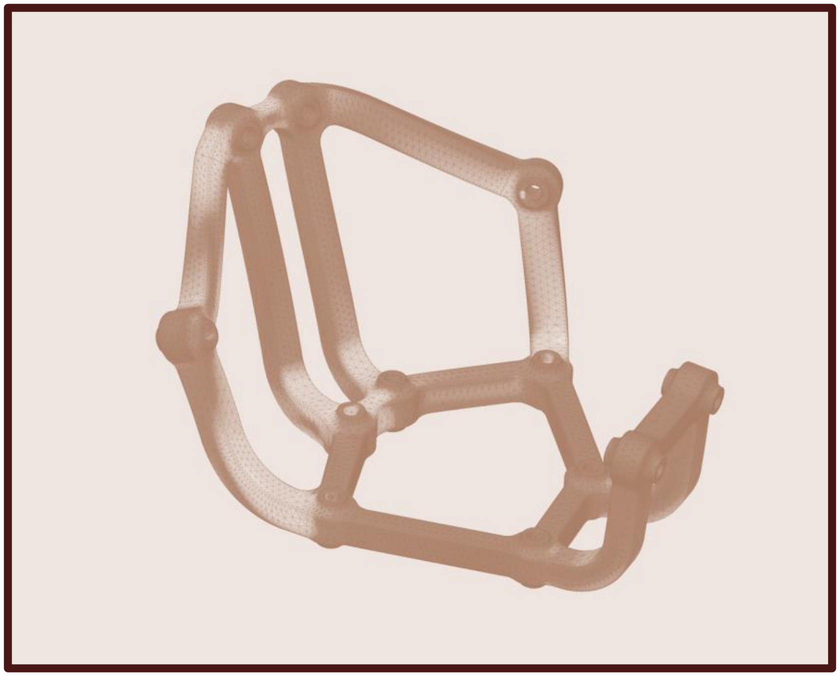
In contrast to Reverse Engineering, Generative Design is one of the newest technology-driven advances. The broad concept is that software tools can produce a given number of design alternatives based on constraints. This functionality leverages capabilities like Topology Optimization, which runs structural simulations and removes material not carrying loads. However, Generative Design also mimics behaviors seen in nature, such as replicating behaviors in the growth of bacteria colonies or the evolution of bone structures to optimize weight-to-strength ratios. Generative Design applies such behaviors to automate the generation of other design possibilities. Considering the busy schedule of today's engineers, an autonomous agent providing them alternatives to consider is extremely advantageous.

Today, Generative Design is based on Finite Element Analysis, which breaks up designs into elements and vertices. As material is removed, the software is actually removing some of those elements that are not load bearing. The final output of this design study is mesh geometry, very much like Reverse Engineering.

Once an engineer has selected one of the designs produced by Generative Design, they will need to use it in the rest of their development process. Some of those use cases include:

- **Mesh-to-Surface:** With this activity, the engineer wants to develop a traditional 3D model from the mesh geometry. This can occur when they want to integrate the Generative Design result with a design created using Parametric and Direct Modeling capabilities.
- **Mesh-to-Print:** Here, the engineer wants to print the design using 3D printing instead of machining methods.
- **Mesh-to-Toolpath:** In this scenario, the engineer wants to use machining to produce the mesh geometry of the Generative Design effort.

As with Reverse Engineering, each of these cases may require modifications. Things like holes, pockets, ribs and more might need to be added for assembly purposes. Other features might need to be removed. Furthermore, components developed in this manner will also likely sit alongside boundary representation models in an assembly. As with Reverse Engineering, working with mesh geometry in traditional CAD applications is disjointed or broken because they do not offer the right combination of capabilities.



3D PRINTING

3D Printing—a production process that creates physical items from 3D models by applying many thin layers of material on top of each other—is one of the most exciting recent advances in design. Engineers use it today to make quick prototypes, and some manufacturers are leveraging the process to make production components.

The input for 3D Printing is mesh geometry. That means engineers must export their 3D models, whether they were built with Parametric, Direct, or even Facet Modeling, and export them as mesh geometry. When this occurs, engineers may need to modify the output by improving mesh quality or adding/removing geometric items such as holes and ribs. This, again, is where traditional CAD applications come up short. They lack the capability to work easily with mesh geometry.

EXCHANGING DESIGNS WITH SUPPLIERS

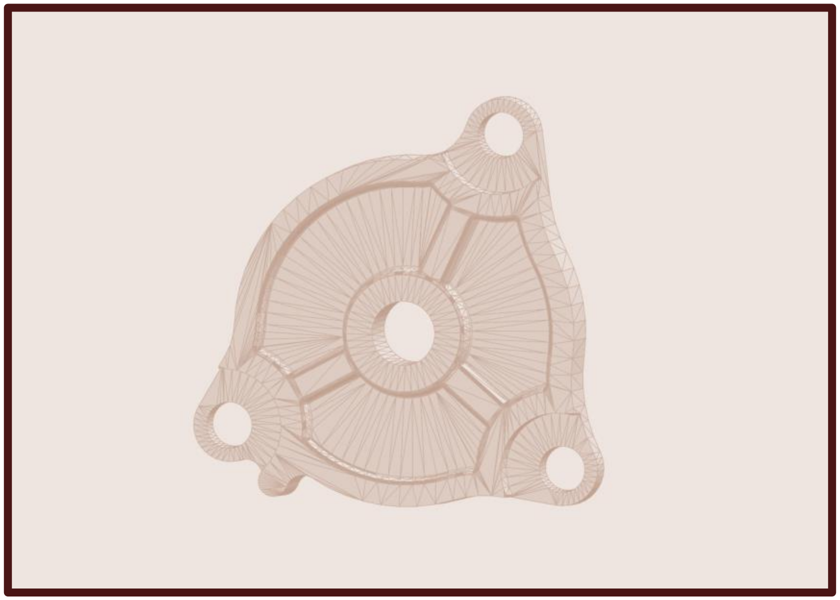
Another scenario where engineers increasingly need to work with mesh geometry is in the exchange of design data with suppliers or part supplier websites. Instead of sharing native CAD files, which sometimes contain design intelligence considered intellectual property, some companies have switched to sharing mesh geometry models. This is especially true of assemblies where standard off-the-shelf components are used. Engineers, as a result, must then incorporate that mesh geometry into their design.

Again, engineers may need to make modifications to work those models into their own designs. Traditional CAD applications fall short here, as they lack the capability to work with mesh geometry.

TAKEAWAYS

In all, there are four distinct scenarios where engineers must work with mesh geometry. Reverse Engineering allows engineers to scan in physical items for replication or as the basis for a new one. Generative Design autonomously produces alternative designs based on constraints. 3D Printing allows engineers to print parts quickly and easily. Some suppliers are choosing to provide digital models in the form of mesh geometry.

In each of these cases, engineers must not only be able to import such mesh models, but must also have the ability to modify them. Traditional CAD applications lack this capability, forcing engineers to use specialty applications that undermine their productivity. They need CAD applications that span Parametric, Direct, and Facet Modeling capabilities.



THE DISJOINTED WORKFLOW USING TRADITIONAL SOLUTIONS

Mesh geometry is becoming a mainstream component of design through Reverse Engineering, Generative Design, 3D Printing, and Design Exchange with Suppliers. Of course, there are traditional technologies that engineers can use to work with these kinds of designs. However, use of those conventional tools often results in a disjointed and broken workflow.

MODELING FUNCTIONALITY

As noted earlier, there are two general forms of traditional geometry modeling. Parametric Modeling lets engineers build a model feature-by-feature, using parametric dimensional controls. Direct Modeling, on the other hand, lets engineers modify existing geometry by pushing, pulling, or dragging it. Both of these modeling approaches work with 'boundary representations,' in which the geometry is represented by flat or smoothly curved surfaces.

Mesh geometry, by contrast, contains a cloud of points representing the outer surface of a design. Some CAD applications turn this into solid geometry by creating planar triangles or trapezoids and stitching them together into a 'watertight' solid. Facet Modeling lets engineers tweak the quality of the resulting mesh as well as modify that geometry by adding or removing material.

Traditional CAD applications used for building 3D models and other items often use some combination of Parametric and Direct Modeling, both of which result in boundary representations. Unfortunately, very few offer Facet Modeling alongside these conventional capabilities.

Because most CAD applications are unable to work with Mesh Geometry, engineers must turn to other solutions. Some standalone specialty applications offer Facet Modeling. Theoretically, engineers can use both traditional CAD applications and these specialty applications together. However, there are numerous drawbacks to this scenario

LEARNING AND RELEARNING APPLICATIONS

It is important remember *context* when assessing any advantages or disadvantages of using one or more technologies. As discussed earlier, engineers in small and mid-sized companies have a slew of responsibilities. They aren't even always at their desk. When they do need to get a task done, it needs to be done efficiently. Otherwise, their productivity suffers.

Therein lies the primary disadvantage of using two separate software tools to work with design geometry: Engineers must learn how to use each of them. This represents an initial investment in time. However, understand that work with Mesh Geometry might be required only occasionally. When an engineer hasn't used that specialty application for three months and must suddenly complete a task with it, they often have to *relearn* how to use it. They must climb that learning curve again. Then, if another month goes by before the engineer must use it again, they will likely go through the same effort. This represents a productivity loss for the engineer and a setback for the development project.

BROKEN DESIGN PROCESSES

Regardless of how many design tools an engineer uses during development, the final step is to provide a single model to downstream participants such as buyers, machinists, testers, and more. This means that any work done in traditional CAD applications and the specialty application must be merged somehow.

If you are familiar with the exchange of geometry between CAD applications, then you are likely familiar with the issues here. Moving a model from one software system to another often results in misaligned or missing surfaces, lines, or points. This 'breaks' the model, because it no longer represents the design. Thus, engineers have to fix these sorts of problems every time geometry moves from one type of software to another.

Moving geometry back and forth between traditional CAD applications and specialty applications is no different. This handoff is subject to the same issues. The result is more time lost for the engineer and a likely setback for the development project.

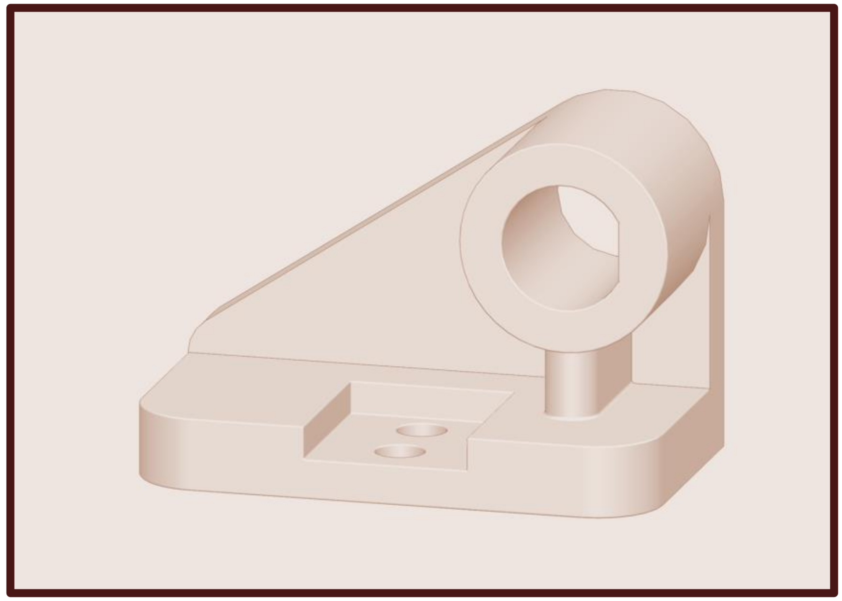
MANAGING YET ANOTHER SOFTWARE APPLICATION

As noted earlier, engineers often have to act as their own IT managers in small and mid-sized companies. Rationalization of software tools, more so than in larger companies, offers advantages to these engineers.

In that light, installing, upgrading, and maintaining the specialty software application is another burden on the already busy engineer. This detracts from the time they would dedicate to design and development.

TAKEAWAYS

Theoretically, an engineer can use the combination of a traditional CAD application for Parametric and Direct Modeling as well as a specialty application for Facet Modeling. However, using those tools raises a number of issues. Engineers must spend time learning and relearning the specialty software. They have to move design geometry back and forth between these tools. They have yet another software tool to manage. All of this takes more time, reduces their productivity, and delays the development schedule.



THE INTEGRATED WORKFLOW OF PROGRESSIVE SOLUTIONS

Engineers who are forced to use two or more applications to work with mesh geometry lose productivity. Fortunately, a few CAD applications have expanded their geometry capabilities to offer an integrated set of Parametric, Direct, and Facet modeling tools. These tools let engineers mix and match these abilities as needed for the task. It supports the following scenarios:

- **Mesh Geometry Alongside Boundary Representations:** With new Facet Modeling capabilities, mesh geometry need not be transformed into boundary representation geometry. Instead, it can be modified as needed and used right alongside models produced with Parametric and Direct Modeling. Designs resulting from Reverse Engineering and Generative Design can be inserted easily alongside traditional geometry.
- **Take Mesh Geometry to Production:** In the past, engineers had to transform mesh geometry into boundary representations before modifying, printing, or machining it. Now, there is no need to take the extra step. Instead, an engineer can simply modify the mesh geometry, adding or removing material as needed, before using it for 3D printing or machining activities. This completely removes an activity that sometimes took a significant amount of time in the past.
- **Tweaking Models for 3D Printing:** Another scenario supported by this kind of integrated technology is tweaking or modifying mesh geometry in preparation for 3D printing. In this case, engineers can modify the model or even change the quality of the mesh geometry before it is sent to a 3D printer. In the past, this had to be transformed into a boundary representation first. Now, this step can be eliminated.

With these capabilities in a single CAD application, engineers in small to mid-sized manufacturers realize significant benefits. They don't have to learn and relearn another software application. They don't have to install and maintain yet another technology. They gain the freedom to mix and match the modeling capabilities that best fit their needs without compromising. Finally, they need not sacrifice productivity.

SUMMARY AND CONCLUSION

Today's engineers in small and mid-sized companies are responsible for a wider range of responsibilities across design, IT, and other areas than are their peers in larger companies. Nevertheless, they face the same tight schedules, so productivity is key both for engineer and the company.

MESH GEOMETRY DESIGN SCENARIOS

Parametric and Direct Modeling are tremendously powerful design capabilities. However, mesh geometry is becoming more mainstream as engineers leverage Reverse Engineering to create digital representations of existing designs and utilize Generative Design to produce a wider variety of functional alternatives that can lead to better products. 3D Printing offers a faster way to create prototypes and even manufacture parts. Suppliers are providing mesh geometry models more frequently. All these scenarios rely on mesh geometry. But it is just as important to integrate these kinds of models with the boundary representation geometry produced by Parametric and Direct Modeling approaches.

A DISJOINTED TRADITIONAL WORKFLOW

Most CAD applications today only offer Parametric and Direct Modeling capabilities. This means that engineers must turn to specialty applications to work with mesh geometry. This presents challenges for engineers, who must learn and then relearn these other tools every time they need to work with mesh geometry. It also presents challenges in moving models back and forth between the two applications, where geometry frequently breaks. This also means that engineers must install, maintain, and upgrade yet another software application.

THE INTEGRATED PROGRESSIVE WORKFLOW

Fortunately, a few CAD applications have combined Parametric, Direct, and Facet Modeling into a single integrated environment. This lets engineers work with the mesh geometry alongside boundary representation geometry. It also means they need not transform mesh geometry into the traditional types created by Parametric and Direct Modeling. Instead, they can manipulate mesh geometry directly and take it to production or 3D printing. This combination of capabilities promises to eliminate many scenarios that waste the time of engineers today, allowing them to get more design work done.

FINAL TAKEAWAYS

For too long, mesh geometry has been considered a fringe case in design. However, as it becomes more mainstream, engineers are losing productivity. CAD applications that offer integrated Parametric, Direct and Facet Modeling capabilities offer real promise to take progressive steps to greater productivity.

Chad Jackson is an analyst, researcher and blogger with Lifecycle Insights, providing insights on technologies that enable engineering, including CAD, CAE, PDM, & PLM.
chad.jackson@lifecycleinsights.com