Automating Design for Manufacturability Testing on 3D CAD Models: Exploring the Capabilities of Elysium's Geode API

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ABSTRACT

A global aerospace manufacturer was evaluating multiple companies to replace a legacy system for conducting Design for Manufacturability (DFM) testing. To demonstrate our ability to meet their needs, I developed code using Elysium's Geode API to automate their tests. This internship project involved learning about manufacturing processes, CAD modeling, and the API, and then implementing the DFM tests with Python. The code successfully automated all DFM tests on the simple 3D CAD models provided by the prospective client, demonstrating the API's ability to recognize relevant geometric features and determine passing and failing cases. Seeing the success of our solution presented during a benchmark meeting, the manufacturer decided to progress further with their evaluation by sending more complex CAD models for testing. Future work will involve refining the code for the new models, with the aim of securing the manufacturer as a client.

1. INTRODUCTION

DFM is the approach to designing products that considers manufacturing feasibility from the initial stages of development. DFM testing evaluates designs against a set of rules to identify potential issues downstream. As the manufacturing industry has digitized, designs have shifted from 2D drawings to 3D CAD models. Software like Elysium's Geode API can now streamline DFM testing by efficiently and consistently applying defined rules. Although no automated solution guarantees perfect accuracy, it is a valuable tool to filter out flaws that are time consuming to detect, allowing the experts to focus on cases that require human judgement.

Early detection of design flaws prevents costly rework and delays, as errors caught later in production have exponentially higher costs. Automation also addresses the broader industry challenge of retaining and distributing manufacturing knowledge. Companies relying on experienced employees to assess and design products may struggle to apply their expertise consistently across sectors as companies grow or globalize. With the ongoing retirement of baby boomers, many of whom hold senior positions, companies risk losing this tacit manufacturing knowledge, potentially leading to future inefficiencies. Automated tests would embed crucial knowledge into software providing longevity, scalability, and consistency.

The prospective client, a global aerospace manufacturer, sought to replace their DFM testing system. As an intern, I developed the code for their provided tests and models and presented the results, demonstrating the API's capabilities and ease of use which allows even a junior developer to create custom DFM tests.

2. RELATED WORKS

Elysium is a leader in 3D geometry processing, with over 35 years of experience in CAD data conversion (Elysium, 2023). One of their products, DFX Analyzer, is a workstation solution that automates checks for manufacturability, assembly, and safety. Their DFM tests verify design quality against predetermined rules informed by industry standards. Their white paper highlights several benefits of automated design quality verification including labor saving, rework prevention, design standardization, and lower verification costs (Elysium, 2024). DFX Analyzer is an out-of-the-box solution that allows users to use default thresholds or their own values for set DFM tests. The Geode API serves as the control behind the product, allowing the workstation to interact with Elysium's geometry kernel and leverage its advanced geometric analyses. While DFX Analyzer is an established product, Geode—now in its first commercial release—is a more flexible alternative, allowing companies to directly develop code for custom DFM tests. This makes Geode more suitable for the prospective client's specific DFM rules.

A case study explored the use of DFMPro, another automated DFM tool, to analyze an electrical plug inlet design (Pista et al. 2018). The paper highlighted the benefits of a DFM approach being increased cost effectiveness, productivity, and product quality. DFMPro by HCL Technologies offers sets of predefined rules for various manufacturing processes, integrating directly into select CAD platforms. In contrast, Geode offers flexibility by being independent of a specific platform. Elysium software translates models to their own ENF (Elysium Neutral File) format, allowing compatibility with over 100 CAD formats (Elysium, 2023). This is ideal for companies on multiple CAD systems, for example from sourcing components from suppliers. Geode's flexibility in format and DFM rules is therefore well suited to the client's needs.

3. PROJECT DESIGN

My involvement in this project spanned approximately one month, from receiving the sample models and test items to the benchmark meeting. This section details the steps taken during this timeline.

3.1 Requirements

From the DFM tests provided, ten test items were identified across four manufacturing processes: Additive, Machining, Sheet Metal, and Casting. I researched these processes to understand the tests' significance in practice. Moving forward, I will focus on two test items. The numbers in the DFM rules have been changed to protect the IP of the client.

3.1.1 DFM Tests

Test item 1 concerned rounded corners for machined parts. In machining, material is removed through drilling, cutting, and sanding. These tools are generally cylindrical and result in radiused internal corners. Radiused corners also have lower stress concentrations than sharp corners, making them more durable. The client set the rule as R > ¼H, with R and H labeled in Figure 1.

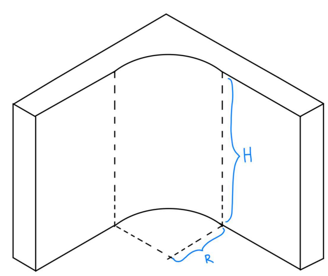

Figure 1. Diagram of a radiused corner, showing radius (R) and height (H)

Test item 2 was for the drill depth of machined parts. Deep drilling can cause heat buildup and accumulate chipped material, potentially causing blockages or deformities. The client sets specific tolerances for a drilled hole based on diameter (D) and height (H). The client defined the relationship H>8D as highly critical and 4D<H<=8D as moderately critical.

3.1.2 Sample Models

Each of the provided models corresponded to one DFM test, and only contained features representing passing and failing cases. I analyzed these models to visualize the features and verify my understanding.

3.2 Geode Training

With my understanding of the DFM tests established, I could identify relevant functionalities as I worked through the training examples. The training material provided by Elysium included code documentation, installation guides, and tutorials for various use cases with annotated Python code and CAD models.

I worked through the tutorials, bookmarking code to potentially implement in my DFM tests. Figure 2 shows the use case for identifying fillets, where the code labels and colors both convex and concave fillets. I anticipated using the concave fillet identification to retrieve rounded corners in a model and incorporating color coding and labeling to distinguish passing and failing cases.

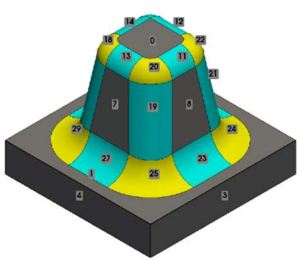

Figure 2: Fillet identification use case. © Elysium Europe SA.

Figure 3 shows the use case for identifying whole, hollow cylinders, which I planned to incorporate in my DFM test for drill depth. This use case also demonstrated the ability to make the CAD models less opaque, which would help ensure reviewers have clear visibility of internal features.

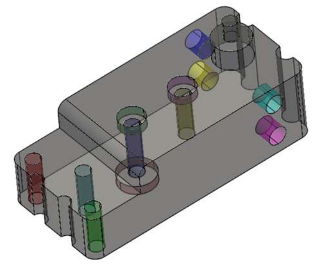

Figure 3: Hole identification use case © Elysium Europe SA.

3.3 Code Development

After extracting the relevant code and verifying that the features could be identified on the client's models, I used the code documentation to incorporate features for extracting information like fillet radii, connected faces, and edge lengths. For test 1, corners were highlighted green or red based on whether they passed the rule for R > ¼H. The labeling feature was then used to display the R and H values that were extracted.

I chose to highlight both passing and failing corners to help identify overlooked cases (the ones left unhighlighted). This way, I could identify any edge cases and amend the code accordingly. Labeling the model with measurements would help future reviewers assess how close the model was to passing the test and provide feedback to the design team.

For the drill depth test, I followed a similar approach, using color coding to represent the criticality levels: red for high, yellow for medium, and green for low. Labels displayed the depth and diameter measurements.

4. RESULTS

All DFM tests were successfully implemented, with 100% accuracy in identifying passing and failing cases in the provided models. I presented these results to the client, showcasing code snippets, screenshots of the annotated models, and time spent on each item. The total time spent on this project was 61 hours, with an estimated 8 additional hours per test for a commercial solution if purchased by the client. This estimate was provided by my manager and would involve further code development by more senior developers in the company.

The project provided two key insights for Elysium. First, it verified that this product had real applications for potential clients, providing encouragement to my managers to pitch the product in future meetings. As Geode is early on in its first commercial release, there has not been much time to verify its utility with consumers, making this benchmark a valuable learning opportunity. Second, the ease of use of this API was established, as the project was completed by me, a summer intern and university student, within a month. This provided confidence that Geode can be easily adopted by companies with their own developers, even without the deep expertise in CAD processing or geometry handling possessed by the developers of the API from Elysium.

5. CONCLUSION

This project demonstrated the potential of Elysium's API to automate DFM testing, addressing an industry need for efficient and consistent manufacturability checks. Geode's compatibility across CAD formats, flexibility to create custom rules, and straightforward implementation make it a viable solution for companies looking to reduce reliance on manual labor in maintaining design quality standards. The API successfully implemented a range of benchmark DFM tests on simple CAD models provided by a real manufacturer. Although the initial benchmark requirements were limited in complexity, it gave the client a promising first look at the API's capabilities and adaptability. This establishes the product's value as a scalable, user-friendly tool that can improve productivity and support knowledge retention in the manufacturing industry.

6. FUTURE WORK

Following the success of the benchmark test, the client decided to continue evaluating the API with more complex models. The next step will be running the existing code on the new models to assess performance and determine any modifications needed for real industry implementation. Future developments will focus on refining the code to accurately identify and evaluate models with intricate geometry. Client feedback from the ongoing evaluation will guide improvements, helping to establish Elysium's product as a robust and adaptable DFM solution. Should the client purchase the solution, additional DFM rules will likely need to be developed to meet further manufacturability constraints.

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