Method to Reverse Engineering International Graphics Exchange Standard (IGES) File into Computer-Aided Design (CAD) File Format.

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1. Introduction

The proposed challenge involved the reconstruction of the given 3D model IGES (.igs) file into an identifiable 3D model and recovering its obfuscated design information. The given IGES file represented a 3D model which was a Computer-Aided Design (CAD) 3D solid model and included its design information (eg: Appearance, Material, Volume) and had a weight of 19.7g. This reconstruction was required to result in a CAD file with recovered design specifications.

2. Analysis of given information

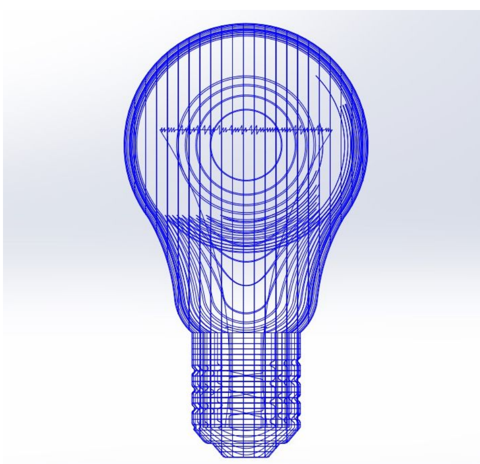

Fig 1: A front plane view of the given IGES File

The challenge provided us with the IGES (.igs) file to identify and replicate the file into a 3D model CAD file. In order to view the file we used CAD software to gather information, and found that the model was not a 3D model but a 3D spline representation of a Filament Light Bulb. To gather further information we decided to open the model as a plain text file ***[Appendix A]*** and found the following:

We learnt that the file was made using Solidworks[1] IGES file using analytical representation for surfaces, by the user named MiddleMac and confirmed that the file was a representation of a Light Bulb. Having found this we decided to use Solidworks to extract further information for replication. We noted that the PART file was converted to a mesh file in an attempt to safeguard the file information.

3. Reverse Engineering the Model

We proceeded to scavenge the mesh file for dimensions of the components and replicated the model on a part by part basis. We isolated the given 3D splines in the IGES File on the CAD software and identified the features.

Fig 2: Replicated model from the given IGES File

As we didn’t have a calibration file with the model so as to determine what materials are used for its components, we decided to use the given weight [of 19.7g] as a method of validation: To determine the materials and design decisions for the final model.

A. Glass Section

Upon isolating the spline set for the glass we discovered that the splines were drawn on x-y & y-z planes and represented the dimensions of bulb in the section cut by them, so we jumped to the center plane to find the radius of glass dome, only to find that there wasn't any section passing from the midplane [center axis] of the model which posed a problem for us, as any offset measurement would mean an inaccurate model.

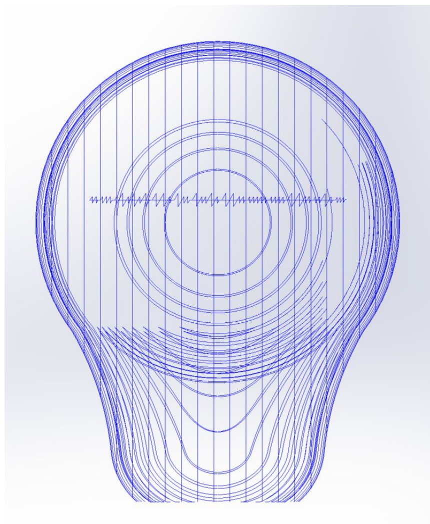

Fig 3: Isolated spline set for the glass section

So, for getting the right curve and the right dimensions of the bulb, we traced the end points of splines lying in x-y plane, on the y-z plane using an overlapping spline and to get the curvature right, we used the outermost curve (which though not passes through the axis of the bulb) as a reference to calculate the tangency at different points of the spline. To keep the bulb center symmetric, rather than drawing the inner surface of the glass like the former method, we calculated the distance between the inner and the outer wire mesh and gave the outer glass surface a depth using the press pull tool.

Section A : This section highlights the thickness of the glass as shown in the section represented by splines.
Section B : This was another section we found during the inspection, which led us to believe that there was a spherical section on the interior of the glass.

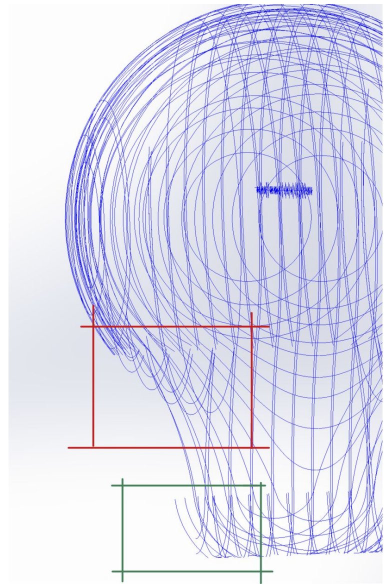

Fig 4: Internal section of the glass

We hypothesized that it would be a solid glass section on the interior, but had no way of identifying whether this hypothesis was right or just an assumption.

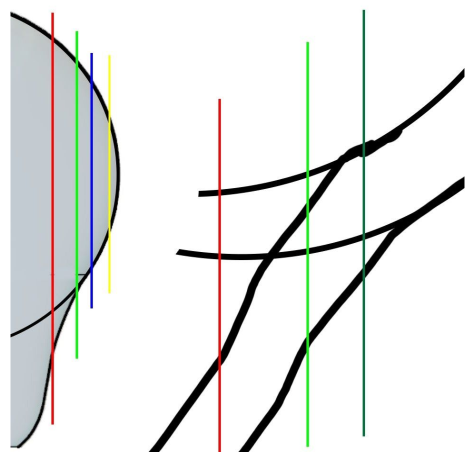

Fig 5: Sketch visualising cross-section of glass

So, we made 2 different glass sections for the bulb which we would later validate using the weight and the materials used.

B. Bulb Socket

We followed suit by isolating the splines for the bulb socket section.The radial dimensions were taken on the x-z plane and similarly found the hollow depth, drafted section length, threading depth and number of revolutions on the y-z plane.

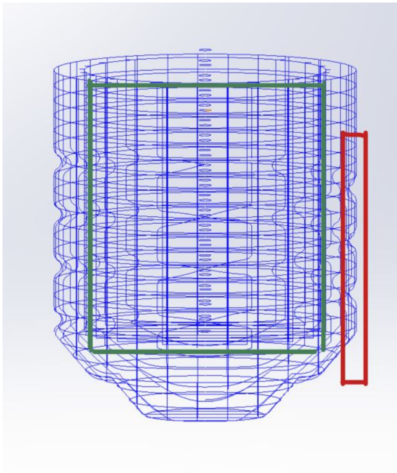

Fig 6: Isolated spline set for bulb holder

The mesh file did not provide any information as to whether this component had multiple parts, as a common bulb has an insulating layer between the conductors. We made another hypothesis that certain information [like: number of solid bodies] had been lost in the attempt to safeguard the file information. We made 2 different models and decided to use our method of validation to determine this after finishing the model.

C. Lead Wire (Filament supports)

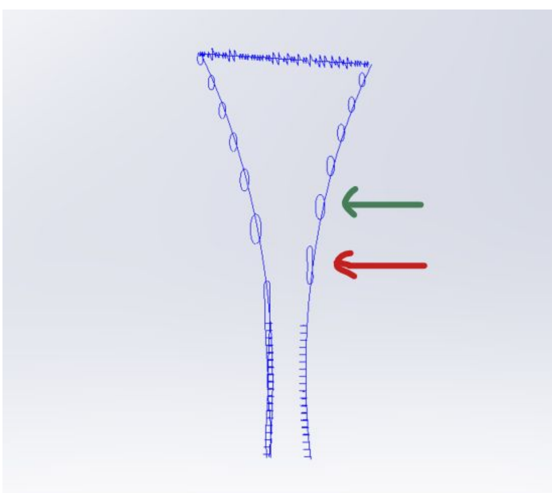

Fig 6: Asymmetrical features on Lead wire

For creating the Lead Wires surface loft tool was used, as the cross-section was varying and not consistent.After the loft, we noticed the features were asymmetrical. [Feature in red is an unexpected asymmetry, as compared to the feature in green]

The right Lead wire loft was shorter because of the lower position of the cross-section spline in that lead. We extracted some features from either of the wires and mirrored them on the other. This was done to compensate for the missing curves on the end of the right lead wire.

D. Filament wire

The filament wire was rather straightforward to work with. We weren't able to find the cross section of the filament wire in the given file, that was assumed to be lost in the conversion. We then sought back to research on the average cross-section of the filament wire on the web, and used the learned value.

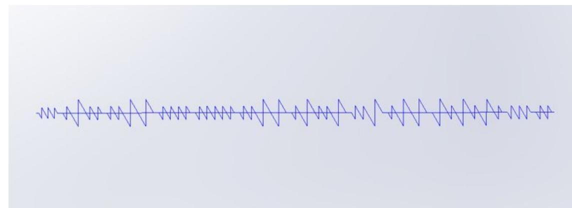

Fig 7: Filament wire

E. Material

Figuring out the right material for the bulb was a foreseen challenge since the very beginning of the competition. Recreating the solid design made us realise that the design deviated very little from the standard design, despite the mentioned irregularities. We chose to go with the standard materials that are used in the bulb making industry. After some research, we short-listed some materials and gathered data to choose a combination which was closest to the weight goal using the following:

Glass section: Soda-Lime Glass [2.5g/cm^3]
Lead wire: Nickel Manganese [8.72g/cm^3]
Filament wire: Tungsten [19.3g/cm^3]
Bulb holder: Aluminium [2.7g/cm^3]
Bulb holder insulating section: 25% foam-glass [1.04g/cm^3]

This was achieved by trial and error with a list of materials we had acquired with research, which helped us break through 2 of our hypotheses. We decided to neglect the internal glass section, as it overshot the weight target by 14%. The insulating bulb socket section helped us achieve the weight target more accurately and reduced error by 2%. So, we decided to include it in our design, this follows with the assumption that there has been information lost in conversion of the given IGES file.

We achieved an error of about 10% w.r.t. desired value of 19.7g.

4. Conclusion

A lot can be said about the Blue Team's ideology behind the process to safeguard the given component's material information, as well as some specific design information, like the filament wire cross-section. They were well aware of the commonality of their design and were discrete only about specific characteristics of the model. But, for someone with a background in design of the specific component, this would be a lot more easier to catch on regardless of the hindrance created by the Security team. A reverse engineering 'attack' on an obfuscated file like the one in the challenge, is only safeguarded from an outsider of the industry, and not the insiders of the industry that the file needs to be attack-proof from.

A little research helped us gather the information we lacked in knowledge of, and helped fill in the gaps for the reverse engineer attack, which for an industry insider would be their specialised knowledge/field.

However, the lost material information that is intentionally obfuscated, does make a difference if the material is a newly discovered breakthrough/exotic. In a similar component set where the materials are determined using static simulation and analysis, we would still be able to determine the properties of the material used by running our own analysis. We might not be able to pinpoint the exact material but, this process does help shortlist the kind of materials the original component can have, reducing our chances of error in following through with a similar attack.

5. Acknowledgement

Dr. Rajesh Kumar for encouraging us with his vision for engineering students and helping us with resources and providing a comfortable environment to work in.

6. References

[1] https://www.solidworks.com/

[2]https://materialslightbulbcomponents.weebly.com/incandescent.html

7. Appendix

A. `SolidWorks IGES file using analytic representation for surfaces`

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1H,,1H;,26HHack3D Lightbulb v2.SLDPRT,97HC:\Users\MiddleMac\Downloads\Convert to
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2020,15HSolidWorks 2020,32,308,15,308,15,26HHack3D
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