School of Computer Sciences

CS-420 Internship: Fillet Recognition

[August 17 - December 31]

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1 January, 2021

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Acknowledgement

First, I am grateful to the Placement Office of Indian Institute of Technology Goa for successfully arranging this internship opportunity for me. I am also grateful to Altair Engineering for recruiting me as an intern.

I am fortunate that, I had the kind of association as well as supervision of my manager Mr. Kedar Patil for his exemplary guidance, monitoring and constant encouragement throughout the course of this internship.

I would like to express my sincere gratitude to my internship coordinator Dr.Amaldev Manuel who has given his valuable time, his great guidelines for internship and coordinated all along my internship having their busy schedule.

Lastly, I would like to thank the IT/Systems team of Altair for making this internship possible, by constantly providing in-time support in time of system issues.

Chapter 1

Introduction

1.1 Problem Statement and Motivation

In a given surface mesh, there are important regions that represent fillets. Filleting is an operation in which sharp edges in the models are rounded off to create smooth transitions between adjacent surfaces. We often need to identify regions in the surface mesh that represent fillets. Such identified fillets can then be meshed using specialized algorithms. The project involves pogrammatically and automatically identifying different kinds of fillet regions in a raw surface mesh, marking the boundaries of fillets (boundaries are curves on mesh that join the fillet surface with adjacent surface) and finding a chain of fillet surfaces.

Once we get the meshed structure of the model some important information is lost like- in the figure below the elements 1,2,3,and 4 belong to different face or geometrical entity and elements 5,6,7 and 8 belong to different face or geometrical entity.

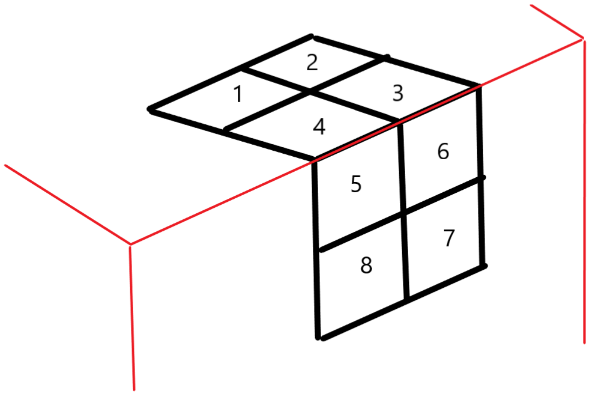

Figure 1.1: Part of a cube whose some meshed part is shown

1.2 Objectives

- Develop automatic fillet recognition functionality in HyperMesh
- **The project will be implemented in C++ as an integral part of HyperMesh.**

1.3 Tools: Hypermesh

HyperMesh is the market-leading, multi-disciplinary finite element pre-processor which manages the generation of the largest, most complex models, starting with the import of a CAD geometry to exporting a ready-to-run solver file.[2]
Other tools that were used in this project are C++(programming language) and Microsoft Visual Studio(Integrated Development Environment).

1.4 Organization

Altair (Nasdaq: ALTR) is a global technology company that provides software and cloud solutions in the areas of data analytics, product development, and high performance computing (HPC). Altair enables organizations in nearly every industry to compete more effectively in a connected world while creating a more sustainable future.[1]
Altair exists to unleash the limitless potential of the creative mind. Altair's vision is to transform customer decision making with data analytics, simulation, and high-performance computing. Altair software enables customers to enhance product performance, compress

development time and reduce costs. For more than 30 years, Altair have been helping their customers integrate electronics and controls with mechanical design to expand product value, develop AI, simulation and data-driven digital twins to drive better decisions, and deliver advanced HPC and cloud solutions to support unlimited idea exploration. In solving their customer's toughest challenges and delivering unparalleled service, Altair is helping the innovators innovate, drive better decisions, and turn today's problems into tomorrow's opportunities.

Altair is leading the global convergence evolution toward smart, connected everything by delivering groundbreaking solutions in data analytics, simulation, high-performance computing and smart connected products (IoT).

Chapter 2

Fillet Detection Algorithm

The Fillet Detection Algorithm existed prior to my joining the organisation.
I have-

- ported it to better structures,
- added some functionalities, and enhanced existing functionalities to solve specific problems.

Lets try to understand what the algorithm is supposed to do with the help of an example. Given below is the figure of a cube whose one side is filleted. The algorithm try to find out the region which is filleted.

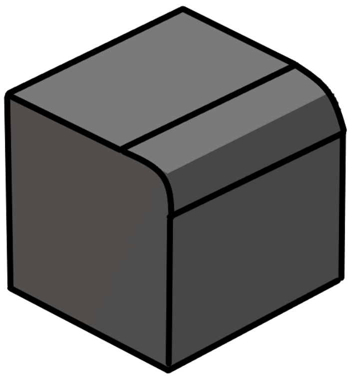

Figure 2.1: Cube with a filleted edge.

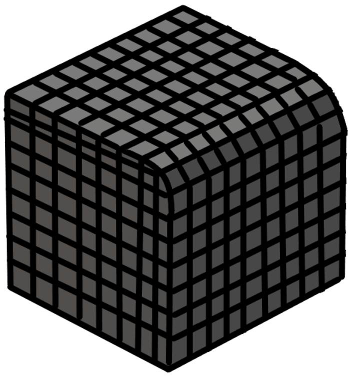

Figure 2.2: Meshed model of above filleted cube.

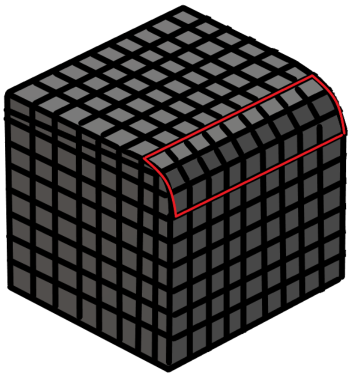

Figure 2.3: Program draws this red line around the filleted region like this

2.1 Algorithm

The program starts with breaking down the meshed model into different simple parts which we call **Topofaces**. Different topofaces of of model are separated by **featured edges**. Featured edges are the edges that separate two elements which are at angle more than **30**°.

Next 2 figures are used as an example to describe the featured edges.The first figure shows a meshed cube which has different element color for different faces. Look at the elements having different color, they are at an angle 90° which is greater than 30°. So, the edge separating them is featured edge and is shown in second figure using yellow line.

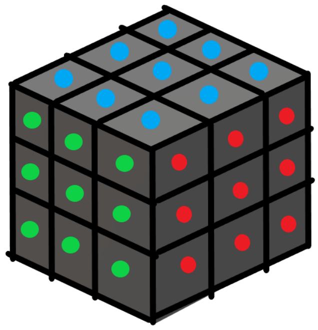

Figure 2.4: Meshed cube with with different coloured elements for different faces.

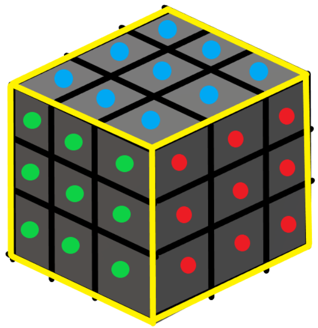

Figure 2.5: Meshed cube with featured edges drawn(highlighted in yellow).

- First, we find all the TopoFaces of the model and iterate over them.
- Find the seed nodes on the TopoFace and call these **Global Seeds** (A seed node is a node which can potentially be in the filleted region.).
- These seed nodes are now explored for generation of fillet boundaries.
  - Construct a plane passing through the seed node.
  - Find points which are on the mesh and are under certain distance from it, call them **band nodes**.
  - We fit circle through the projected points and them trim the circle at appropriate points, call them **lateral nodes**.
- From this seed node we find another node which has the potential of being seed node and then explore it.

Chapter 3

Results

3.1 Results on an actual model

- The image below shows the model that is used for demonstration of results.

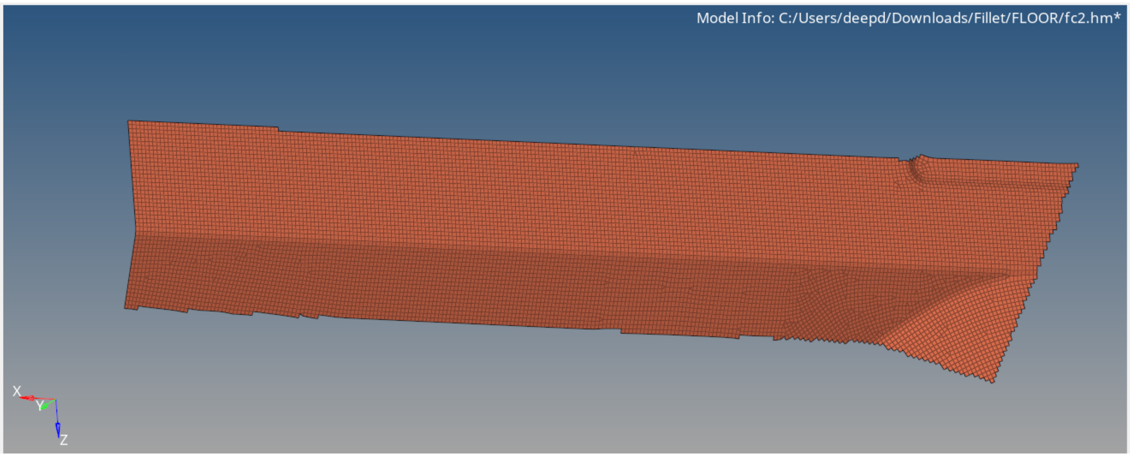

Figure 3.1: Model for demonstration

Since out feature angle is 30 degree and this model the angle between the faces is less than 30 degree so there is only one topoface which is the model itself.

- After performing clustering of nodes in our model based on certain parameters. The centroid of these clusters are our Global Seed nodes. The image below shows the global seed nodes in our demonstrative model-

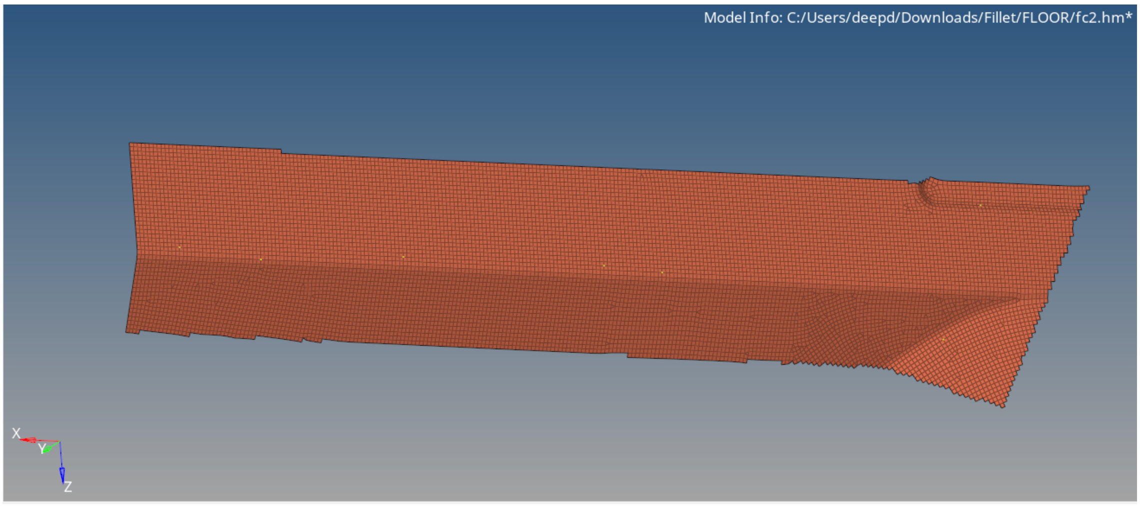

Figure 3.2: Global Seeds (Yellow dots represent seed nodes)

- For a given seed node the image below shows its band nodes-

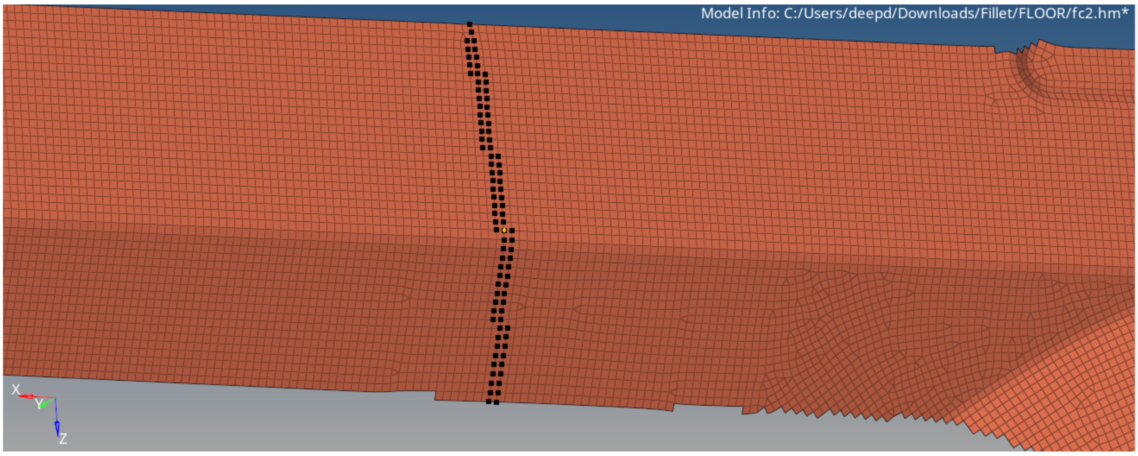

Figure 3.3: BandNodes of the seed point

- After getting the band nodes we are filtering the nodes which satisfy certain conditions of curvature and are under certain distance from their respective seed node. Below image shows the filtered nodes which can be called **Trim domain nodes-**

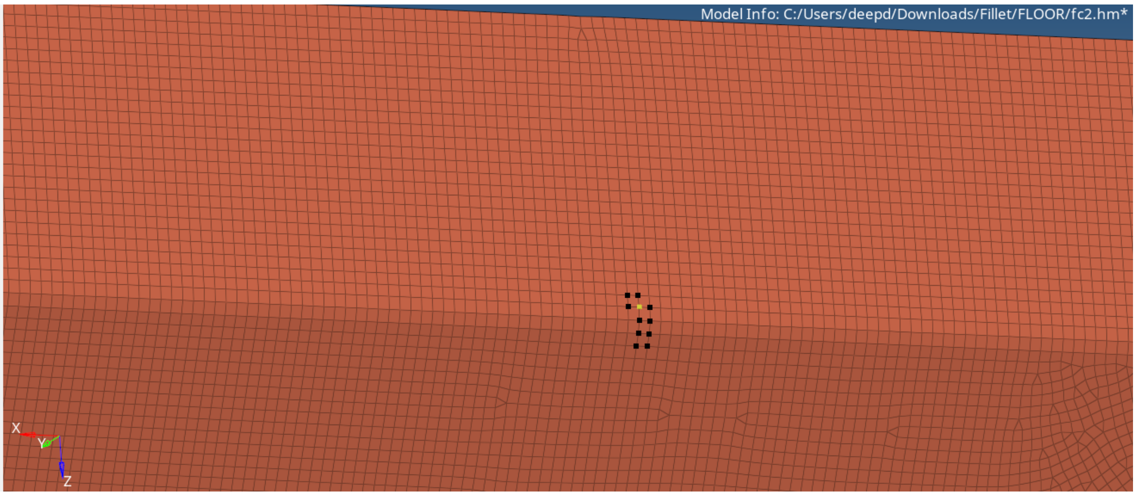

Figure 3.4: Trim Domain Nodes of the seed point

- These trim domain nodes are now projected onto the plane of seed node. We try to fit a circle through the projected points and then trim it. The image for lateral nodes will be at last.

- Now we find next seed node from this seed node-

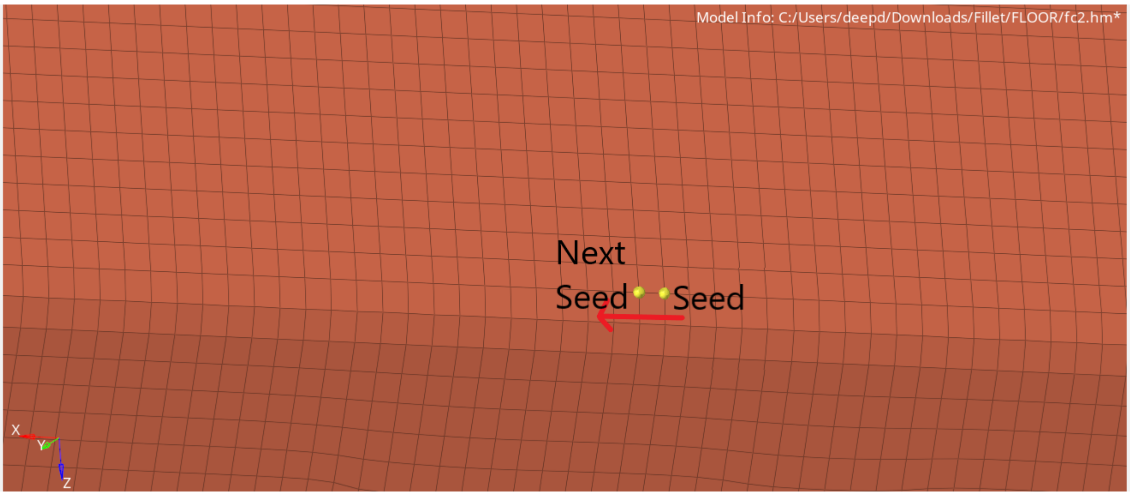

Figure 3.5: Next Seed

- Complete seed exploration of model is shown in below figure-

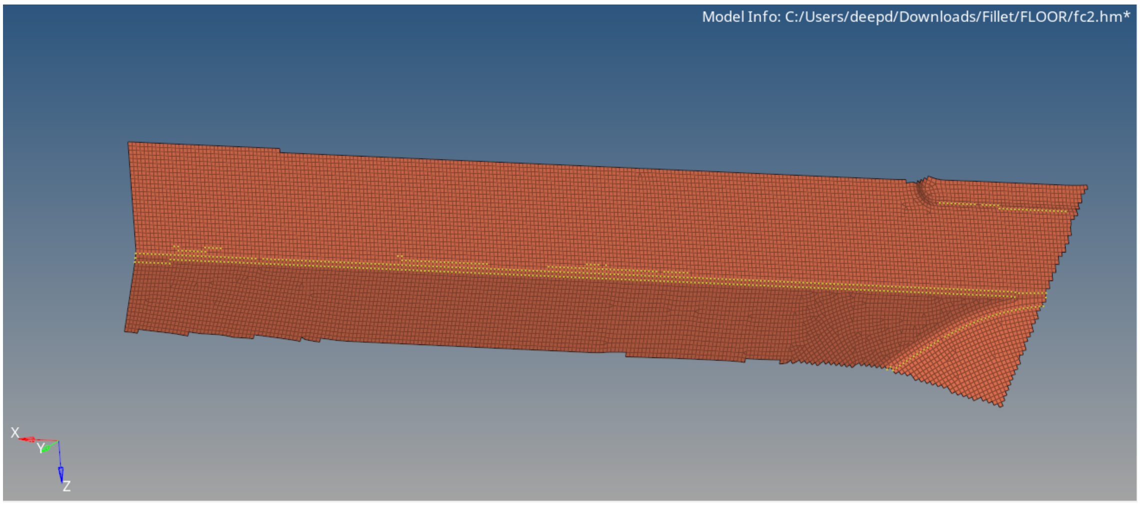

Figure 3.6: Seed Exploration

- Plot of Lateral Nodes-

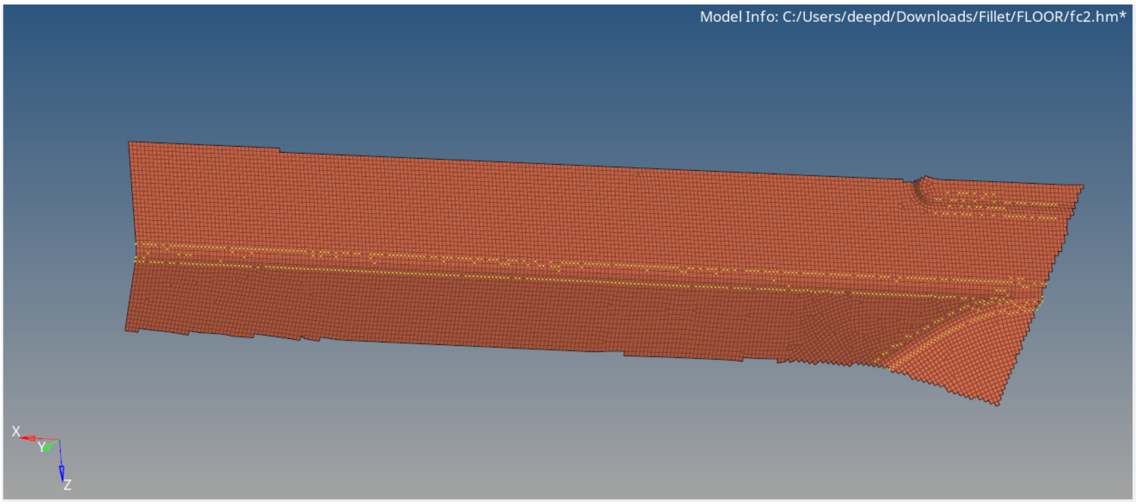

Figure 3.7: Lateral Nodes

- Work has been done upto this point and from this point we were to join the lateral nodes with some splines curves to get the open fillet. The expected outcome was supposed to be like the image below-

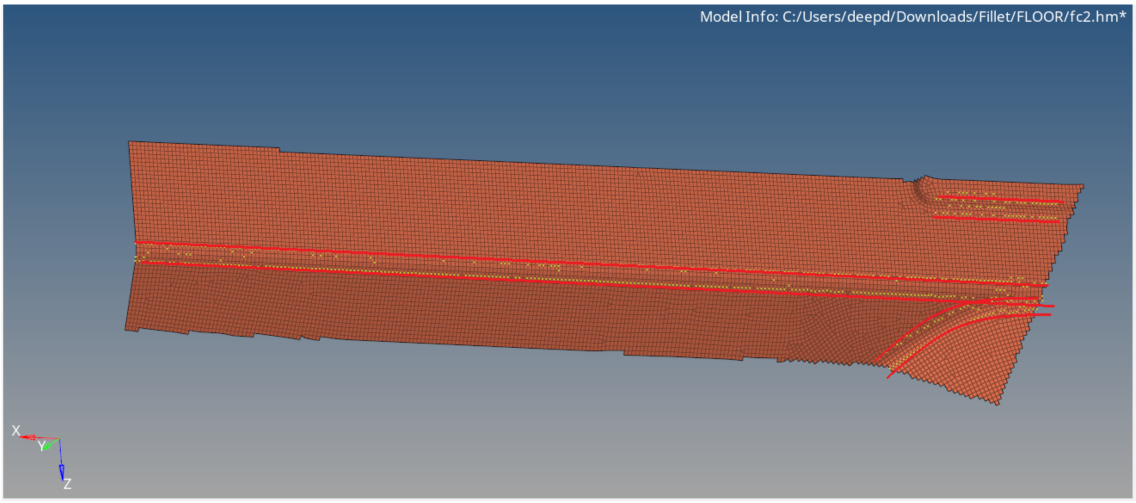

Figure 3.8: Expected Open Fillet

Chapter 4

Conclusion

Fillet recognition is a very challenging task and an unsolved problem in full generality in most of the Computer-aided engineering(CAE) industry. The main challenges are -

- Fillet boundary curves separate fillet surface and adjacent surface. Tracing such a curve that separates smoothly joining surfaces is very challenging.
- Interaction between different fillets can be very complex to recognize.
- Even mildly noisy meshes pose difficulties in terms of finding fillet regions, boundaries and interaction with other fillets. Need to use statistical (machine learning) techniques to address noise.
- Programming solutions require ideas from various fields such as differential and computational geometry, statistical (machine) learning.
- Since there aren't many known researched methods that solve the problem, we need to research and innovate.

To avoid multiple exploration of same segment of model we were marking the global seed nodes as visited if they fell into some explored seeds trim domain nodes. But our model was not getting explored completely. We were stuck on this problem for over a long time, then we found the bug in our program, i.e. our plane normal was getting flipped and we were redirected to earlier explored part thus not exploring some regions. In the image below, the exploration should have been like we start from the starting seed take arrow 1 then from the next seed we should have taken arrow 2 to find the next seed in

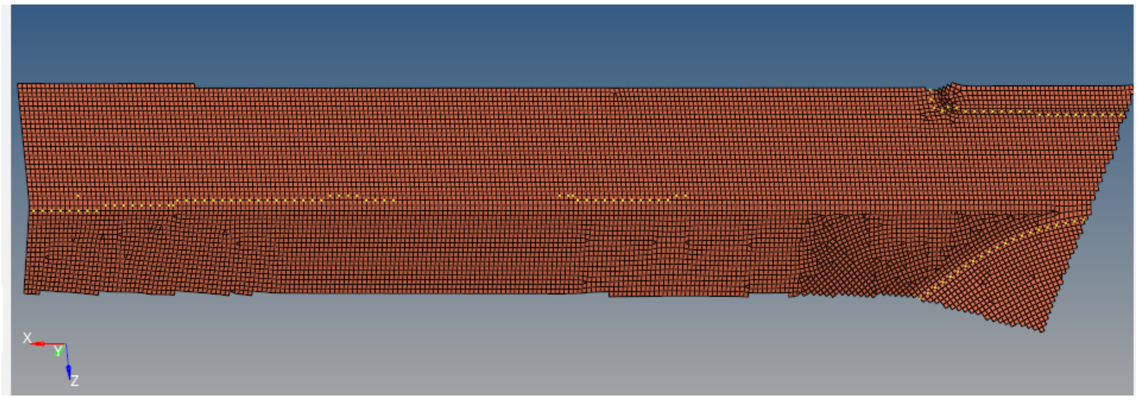

Figure 4.1: Incomplete Exploration

the traversing direction but we went with arrow 3 and reached wrong next seed even from there we should have taken arrow 4 for finding next seed in that direction but we went with arrow 5 thus right side of the model was not explored.

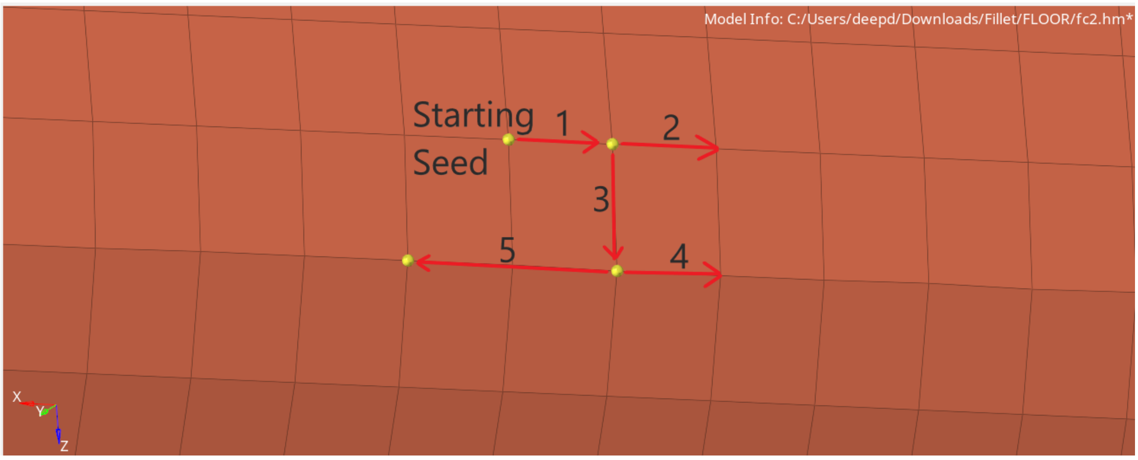

Figure 4.2: Incorrect exploration due to Normal flipping of plane on seeds.

References

[1] Altair. URL: https://www.linkedin.com/company/altair-engineering/about/.

[2] Altair. *HyperMesh*. URL: https://www.altair.com/hypermesh/.