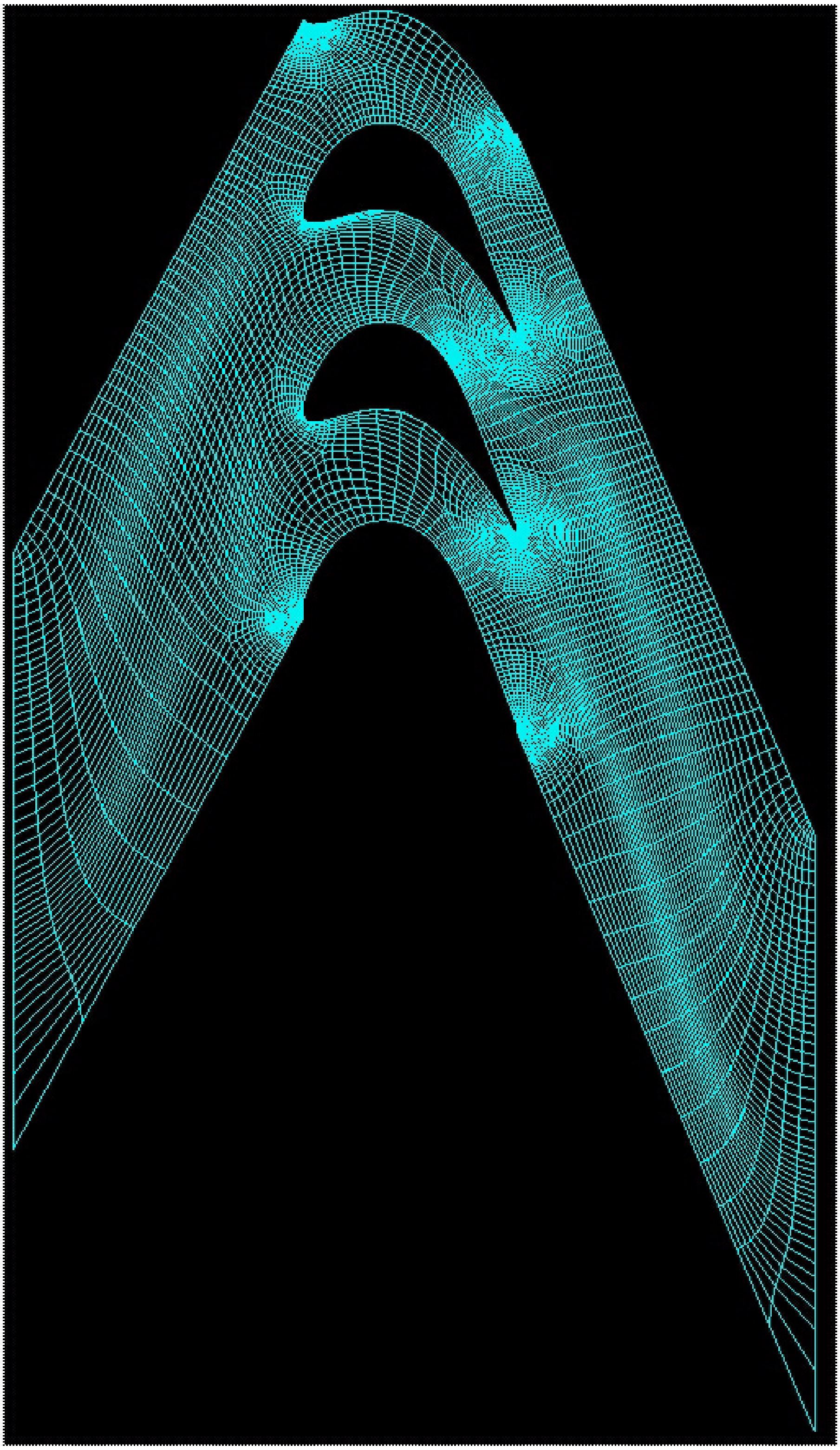
Tutorial 12: Topology design for a curved test section

In this tutorial, you will be dealing with a case which is closer to a real world case. Practical cases usually have more complex geometries, and when using GridPro for such cases, you need to be armed with some techniques to solve these tougher problems. This tutorial will teach you some of the techniques.

Many times, when creating topologies for practical cases, you come across singularities. You will have to ensure that you handle these singularities appropriately to get the high quality grid you desire. Sometimes, the topology may be such that it leads to a high amount of streching in the grids. You will learn that you can alter your topology design to avoid such bad qualities. And finally, to realise the higher purpose of grid generation, you might want to take the flow physics into consideration. For example, you might like a higher concentration of points near the trailing edge of the blade. An elegant and powerful method to accomplish this is by adding an internal surface near the trailing edge of the blade. Adding internal surfaces can help you control grid concentrations in different regions.

In this tutorial you will be gridding a curved test section with 2 turbine blades which is intended to simulate turning flow past the blades. You will start by constructing a simple topology, and successively correct and improve the topology using different techniques to improve the grid quality, and learning some techniques of topology design in the process.

A curved test section for Turbine blades



What You Will Learn

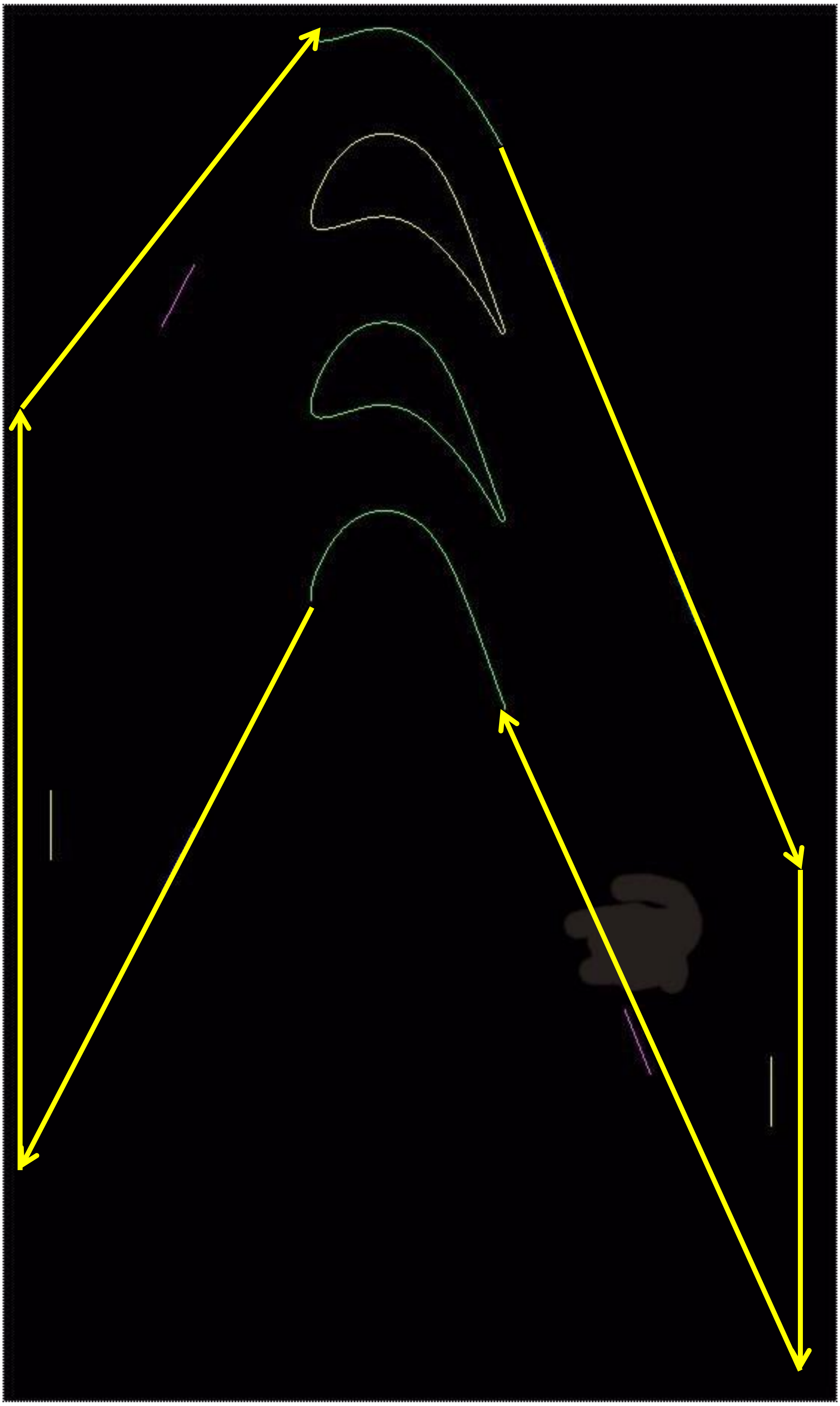
- Avoiding singularities by splitting corners
- Avoiding Stretching of the grid by redirecting the flow of grid lines
- Adding internal surfaces to improve the grid at vital points
- Using the cut-plane to create surfaces efficiently
- Wrapping a group with respect to another group
- Using some functions of GridPro to make your work fast and efficient - like the r-lk button.

Step 1 Load the Geometry

Load the **tutorial_12.fra** file into the graphic manager. Make sure that the surface files that this TIL file refers to are accessible by the graphic manager.

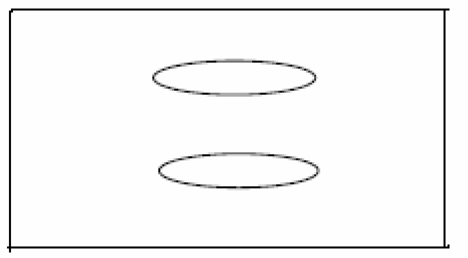
You should be able to see the surfaces as shown in the next page. As you can see, the geometry consists of two turbine blades in a curved test section. Study the geometry and understand it before you move on create the topology for this.

The surfaces (with a rouch sketch of the boundary)

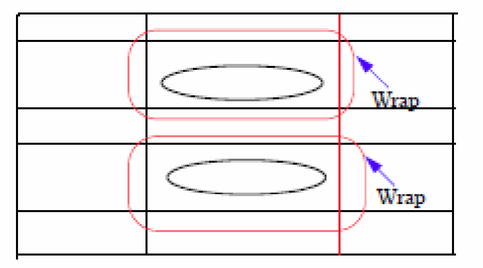


Step 2 Creating a simple topology

Note that this geometry is topological similar to a geometry like the one shown below.



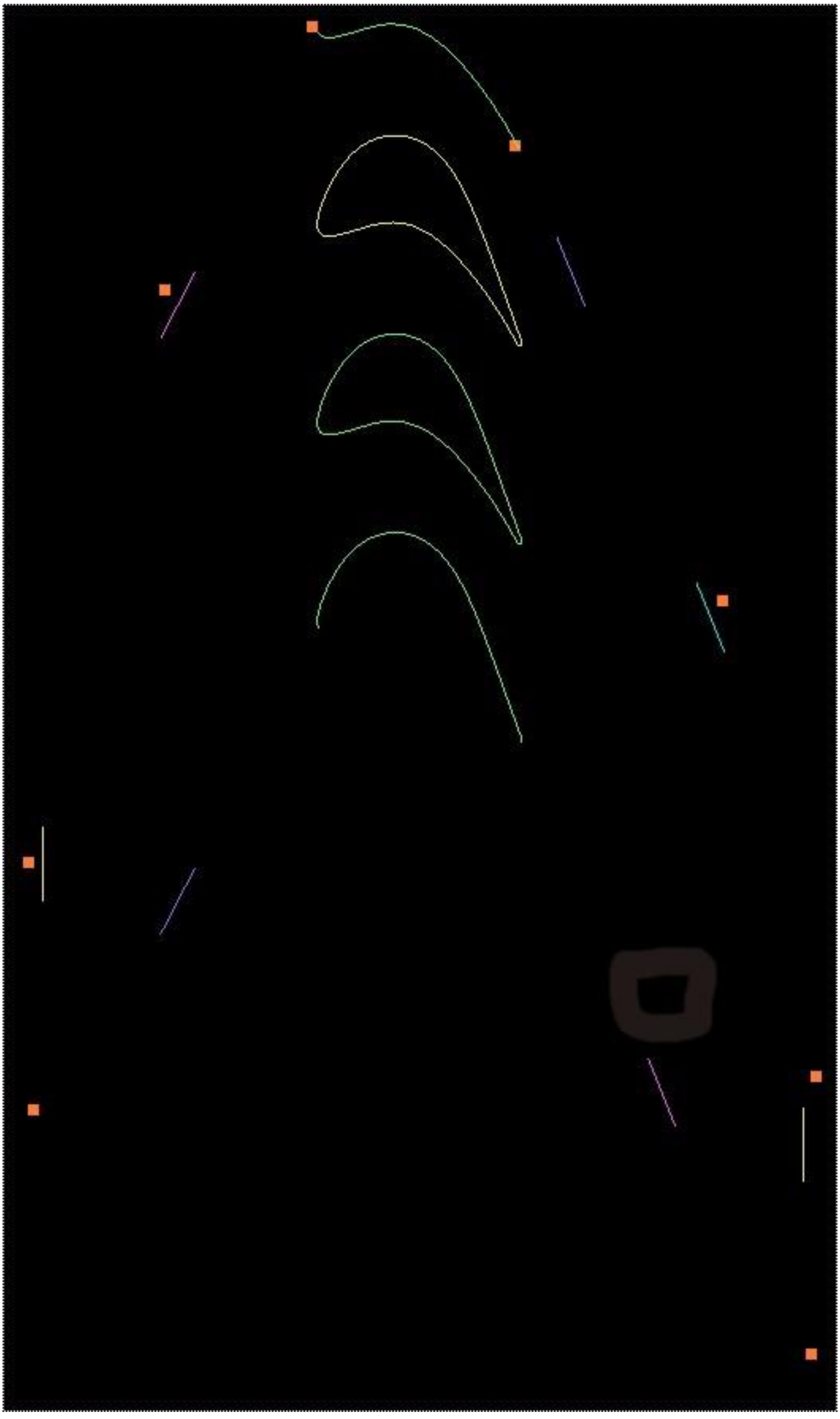
The topology you will generate for the above geometry will be something like this.



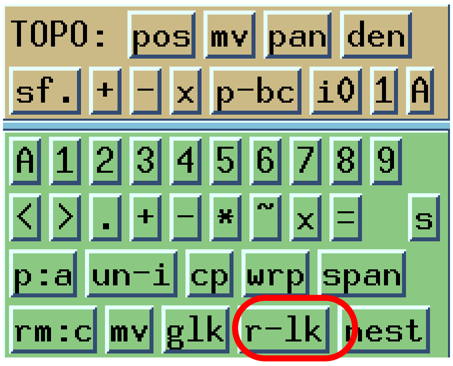
Sometimes, we can figure out ways to create topologies by finding out topological similarities between cases like this. You now have an idea of how to go about creating the topology for the given geometry. Just create the boundary topology, and then insert corners to box in the two blades, and then wrap this inner box as you would have done for the simpler case shown above.

First, create corners along the upper boundary as shown below.

Corners along the upper boundary



After this, you are probably getting ready to link them pressing the **E** and manually clicking on the consequtive corners. This can be a tedious task if there are a lot of points to be linked. Here, you can take advantage of the **r-lk** (region-link) function in the TOPO panel.



Click on the **r-lk** button. You will see a message on the left-top corner of the screen asking you to please do 1 or 2 regional selections. Now, using the right mouse button, drag a box large enough to include all the points in the outer boundary as shown below. After you do so, you will see that the corners in the outer boundary have been linked the way you want them to.

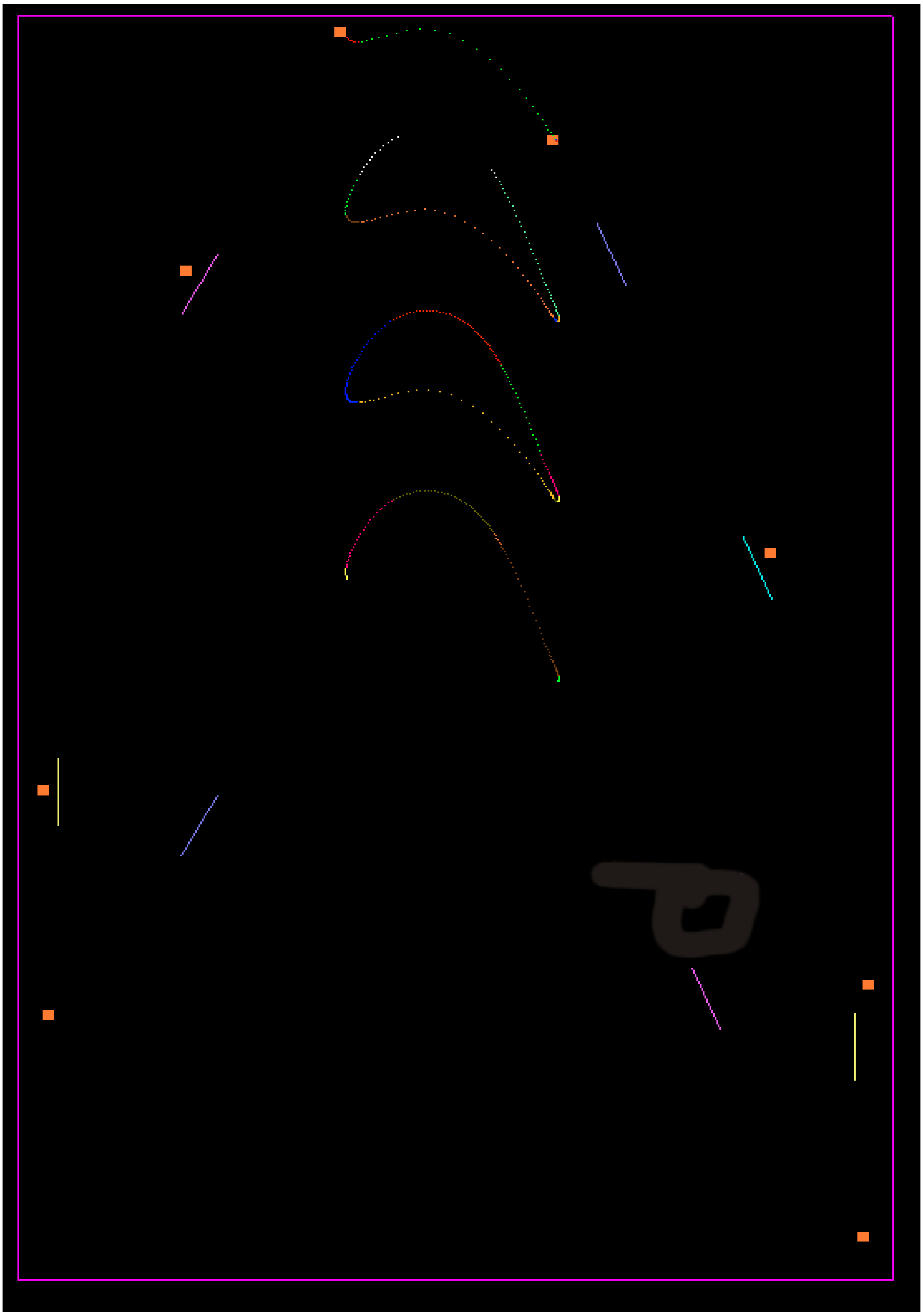
The r-lk button

The **r-lk** can be very useful when you want to link a large number of corners. It links a corner in the region to its nearest neighbor. You will have to remember this when you use this function, and select regions appropriately. As you will see, **r-lk** can also be used to create links between two regions.

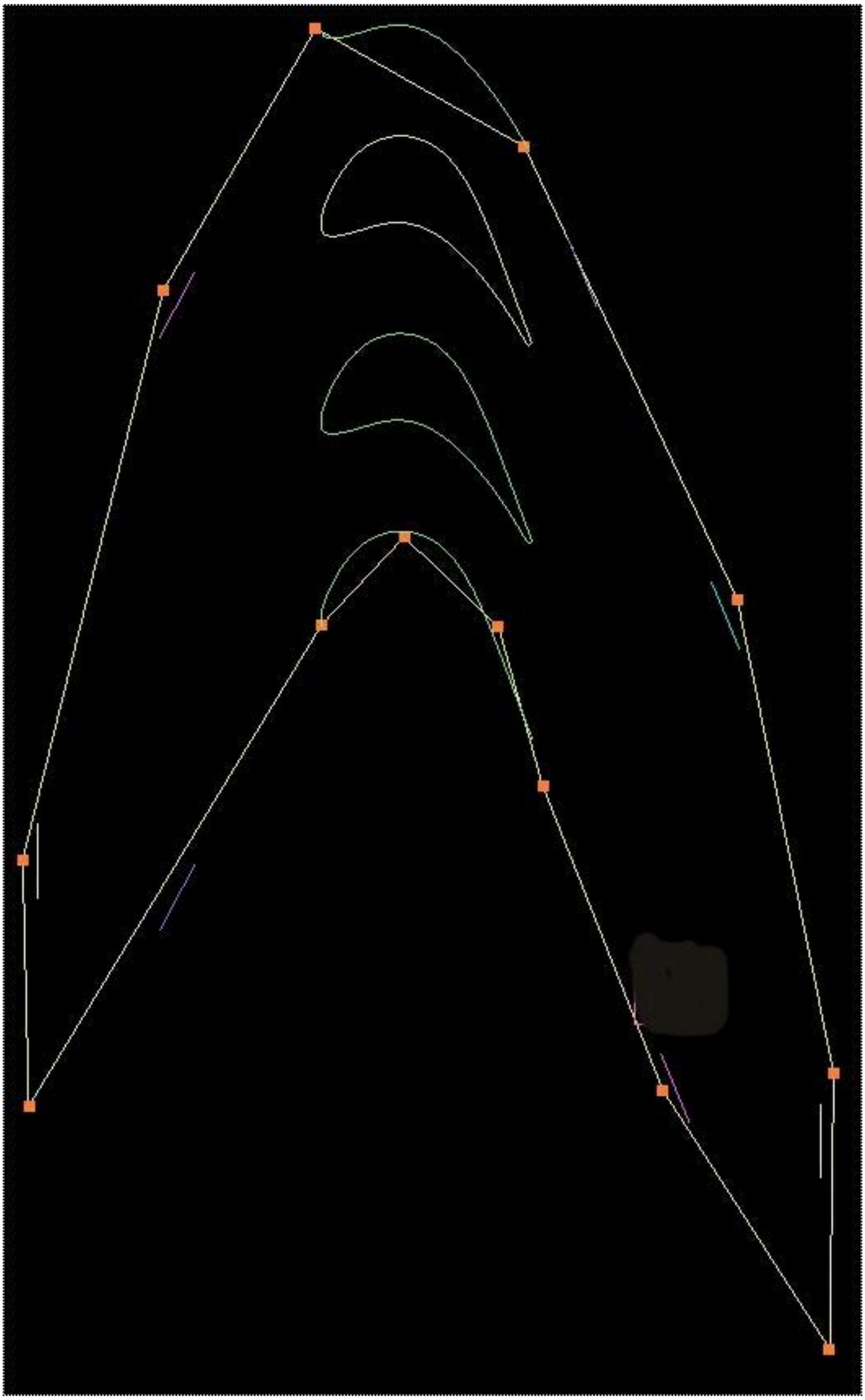
Similarly, create corners along the lower boundary as shown, and r-link them to create the lower boundary. You might find that it is easier to use the **E** key for some corners and then use the **r-lk** button to create the other links.

r-linking

Create a box large enough to contain all the corners

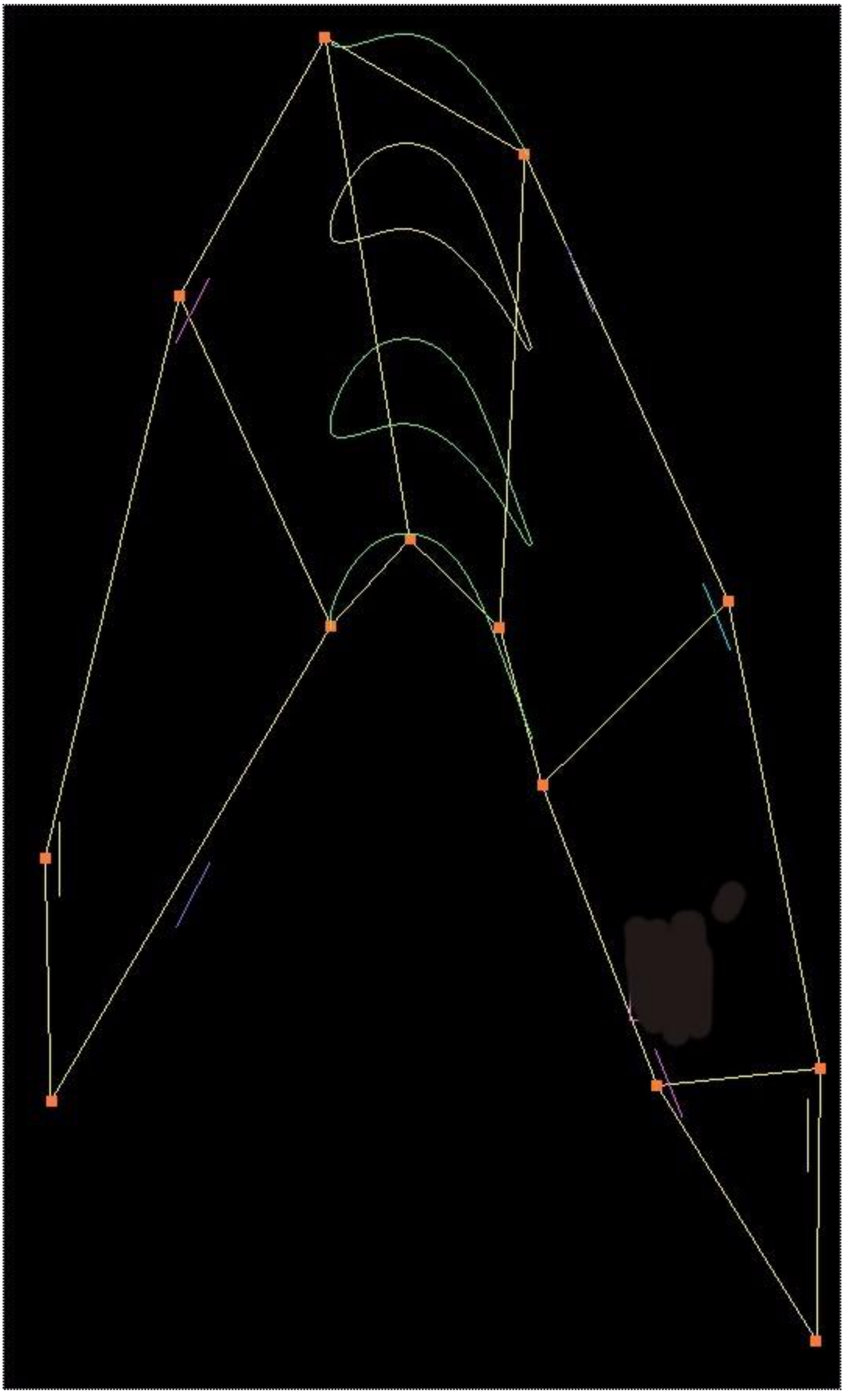


The boundary

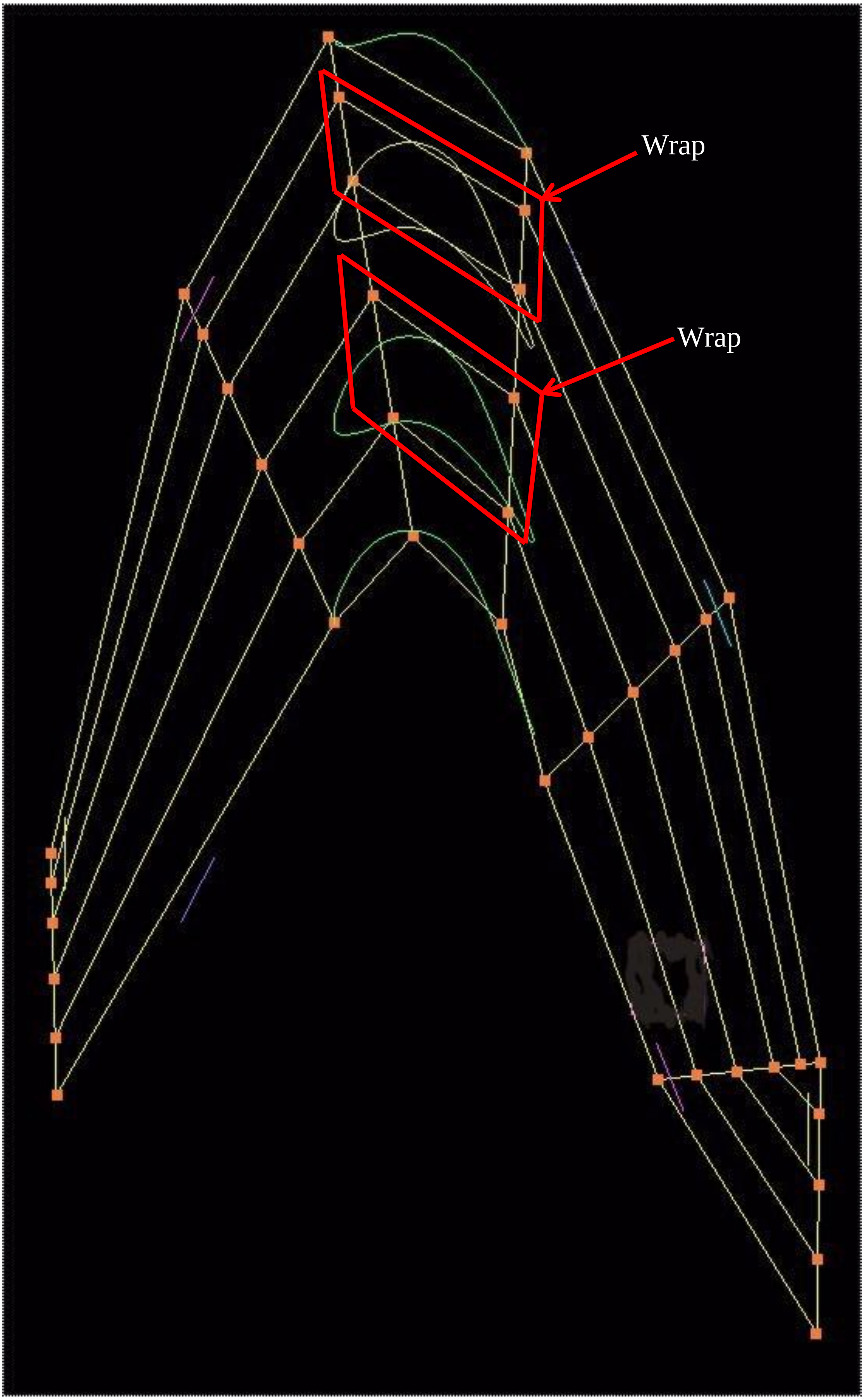


Connect the upper corners to the lower ones to create a topology like the one shown below.

Connect Upper corners to Lower corners

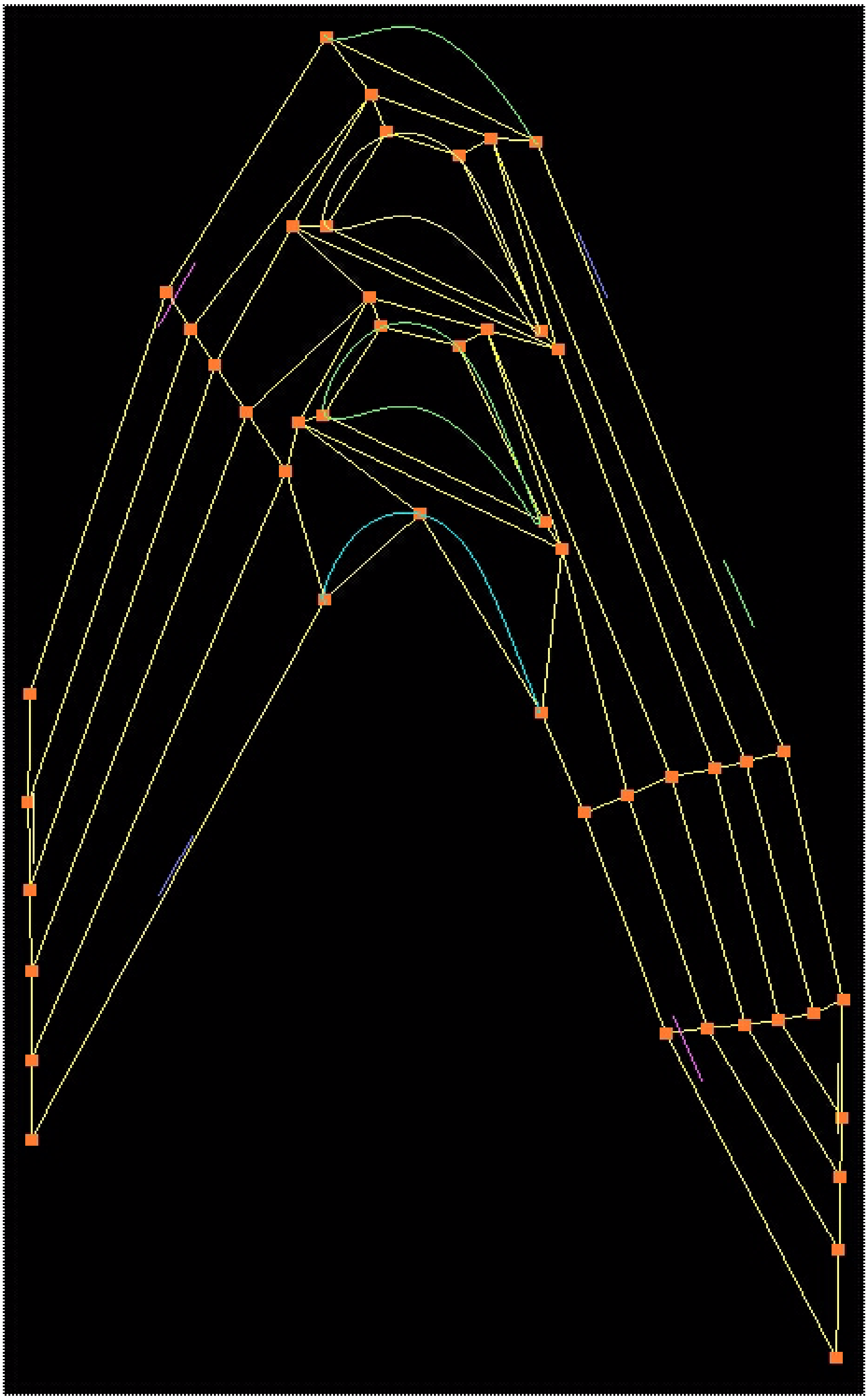


Now, insert edges along any of these lines (connecting the upper and lower) to create a topology as shown below.



Wrap
Wrap

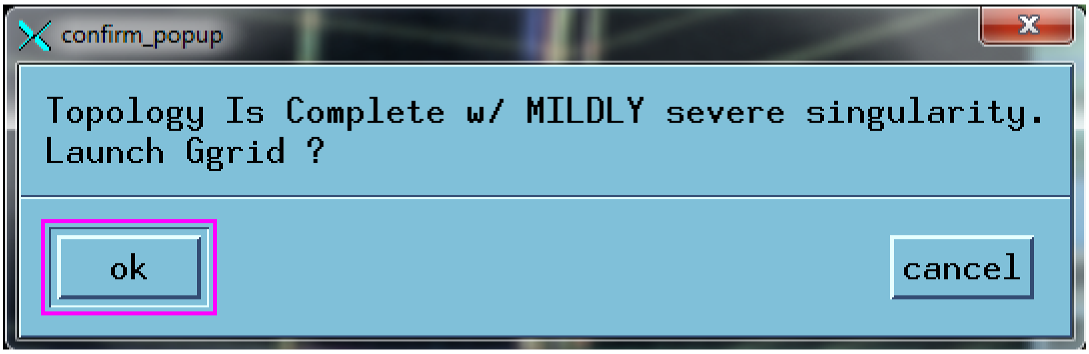
Note that the blades have been boxed in. Now, add this box to a group and wrap the group. After you created the wrap you should get a topology that looks like this.



In the above figure, corners have been moved around to make the topology conform to the geometry. (This will help accelerate the convergence)

Now, you might think the topology construction is complete. Let's say you are right for the moment. All you have to do now is to assign the corners to the appropriate surfaces. Assign the inner wraps to the blades, and you can assign the appropriate corners to the boundary surfaces. You should now be experienced enough to figure this out by yourself. To help you, the surface assignments have been shown in the next few pages.

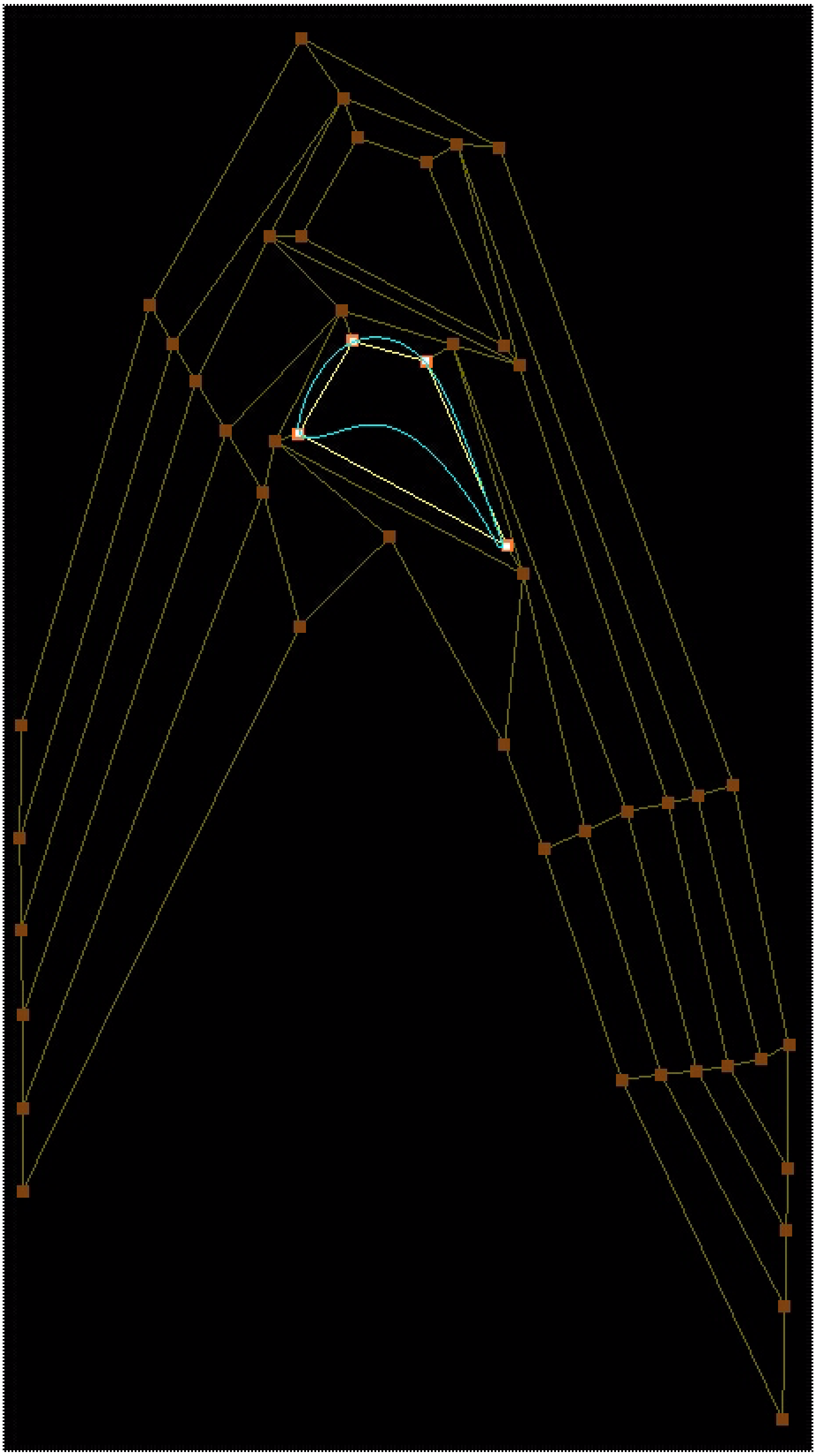
After you have done the surface assignments, you can start the gridding process. You will get a warning message saying that the topology has a Mildly severe singularity.

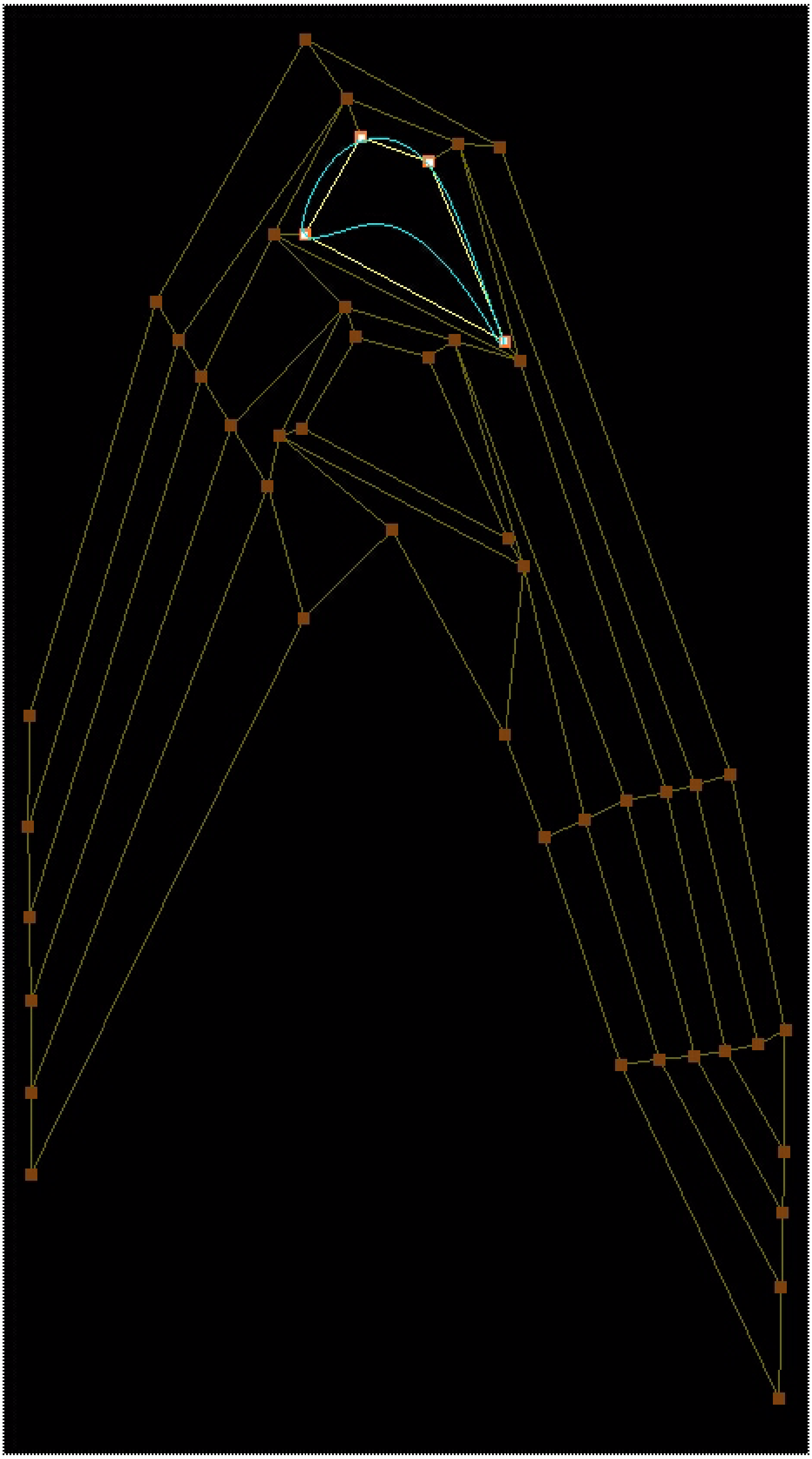


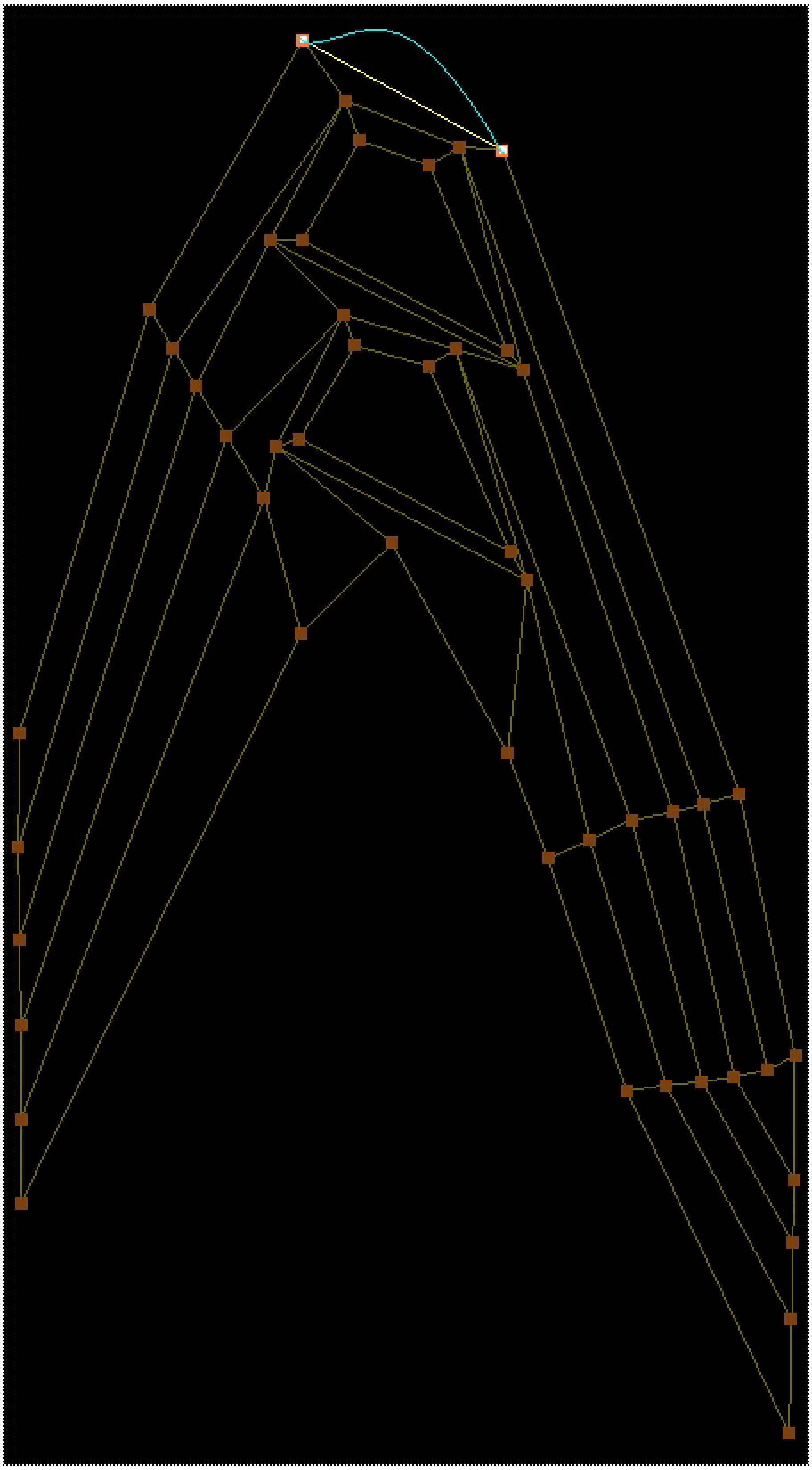
Go ahead and say **ok** anyway. Look at the grid it generates.

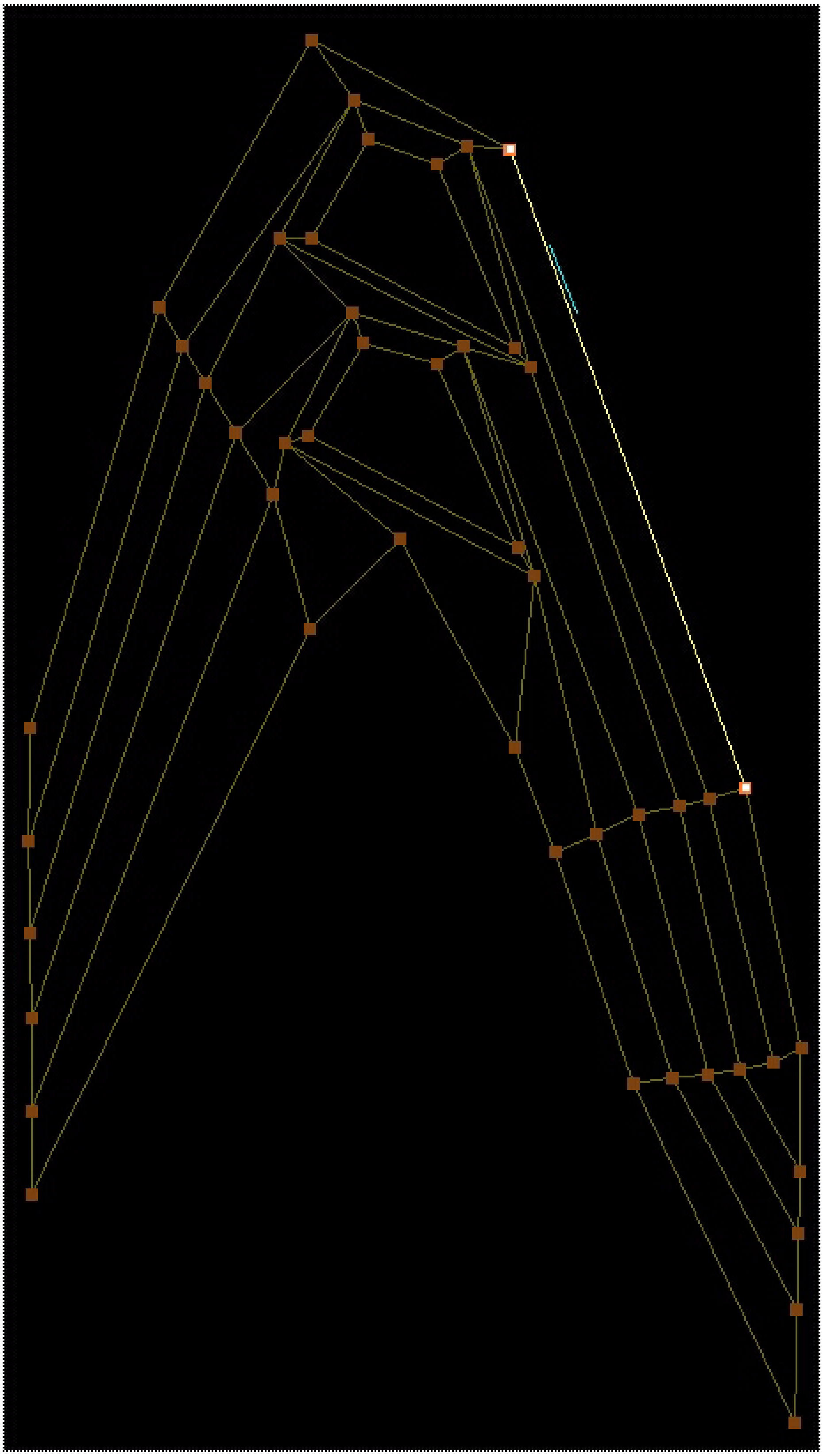
The next few pages will contain a sequence of images showing the surface assignments. Try to use this just as a check.

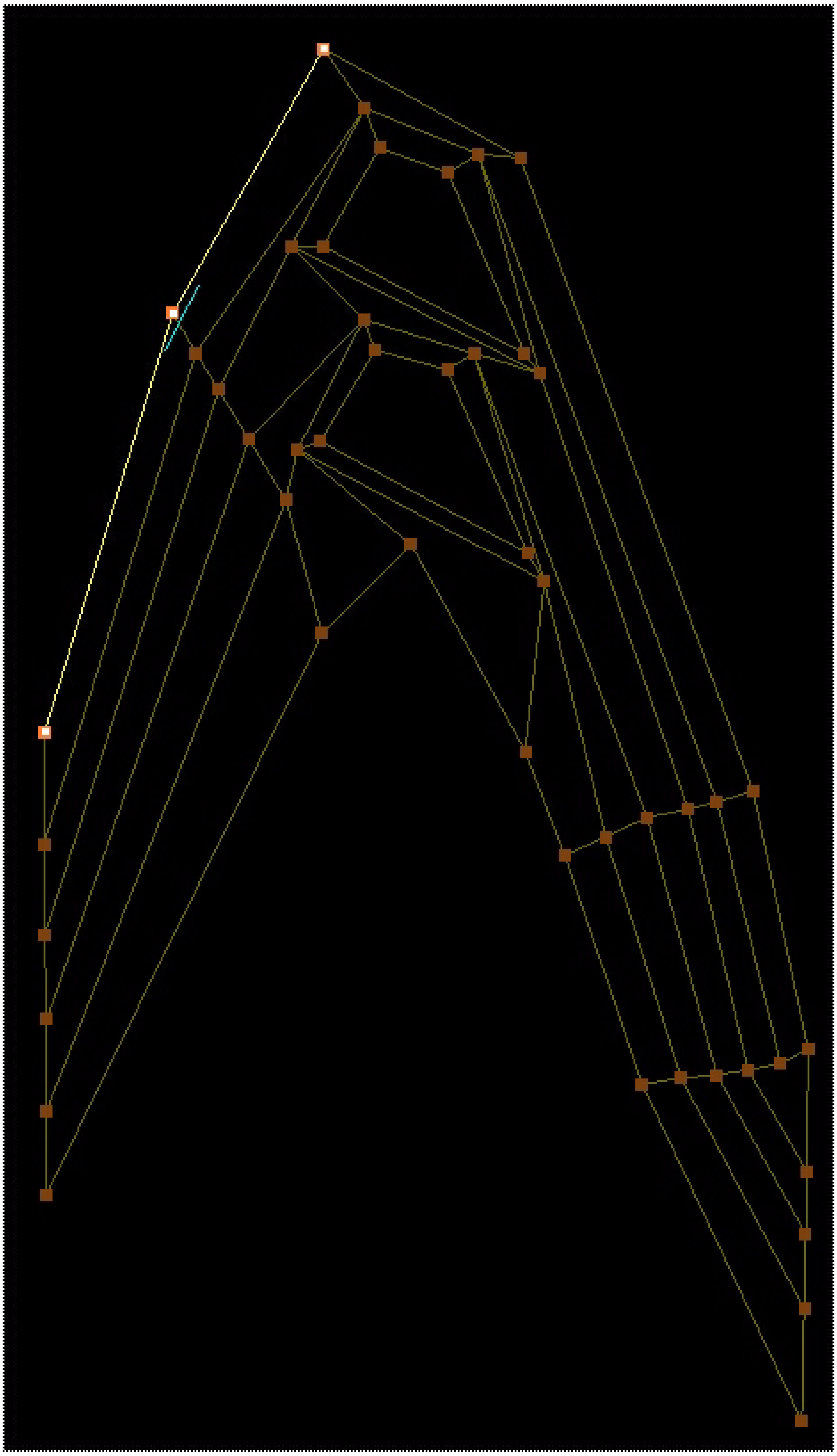
SURFACE ASSIGNMENTS

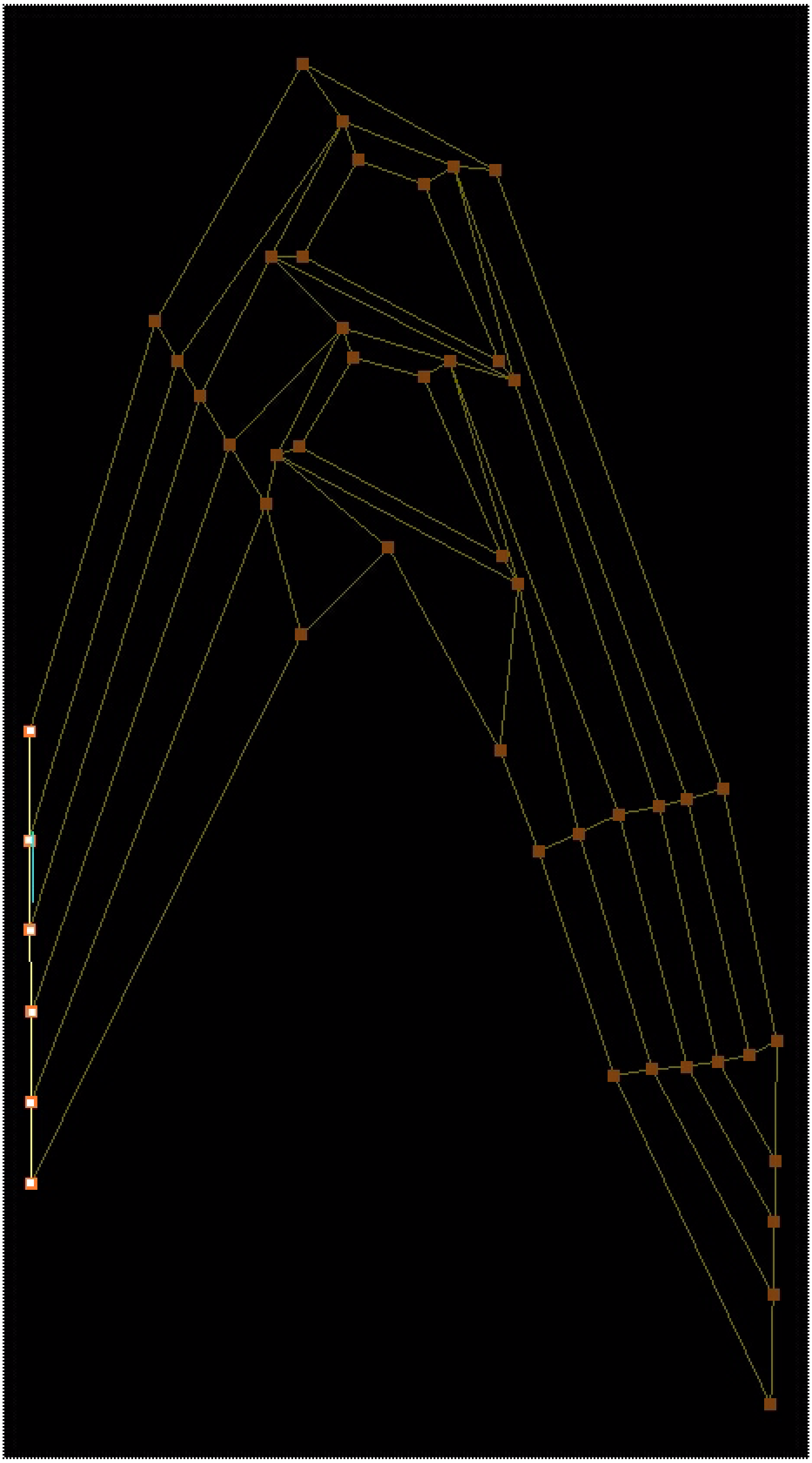


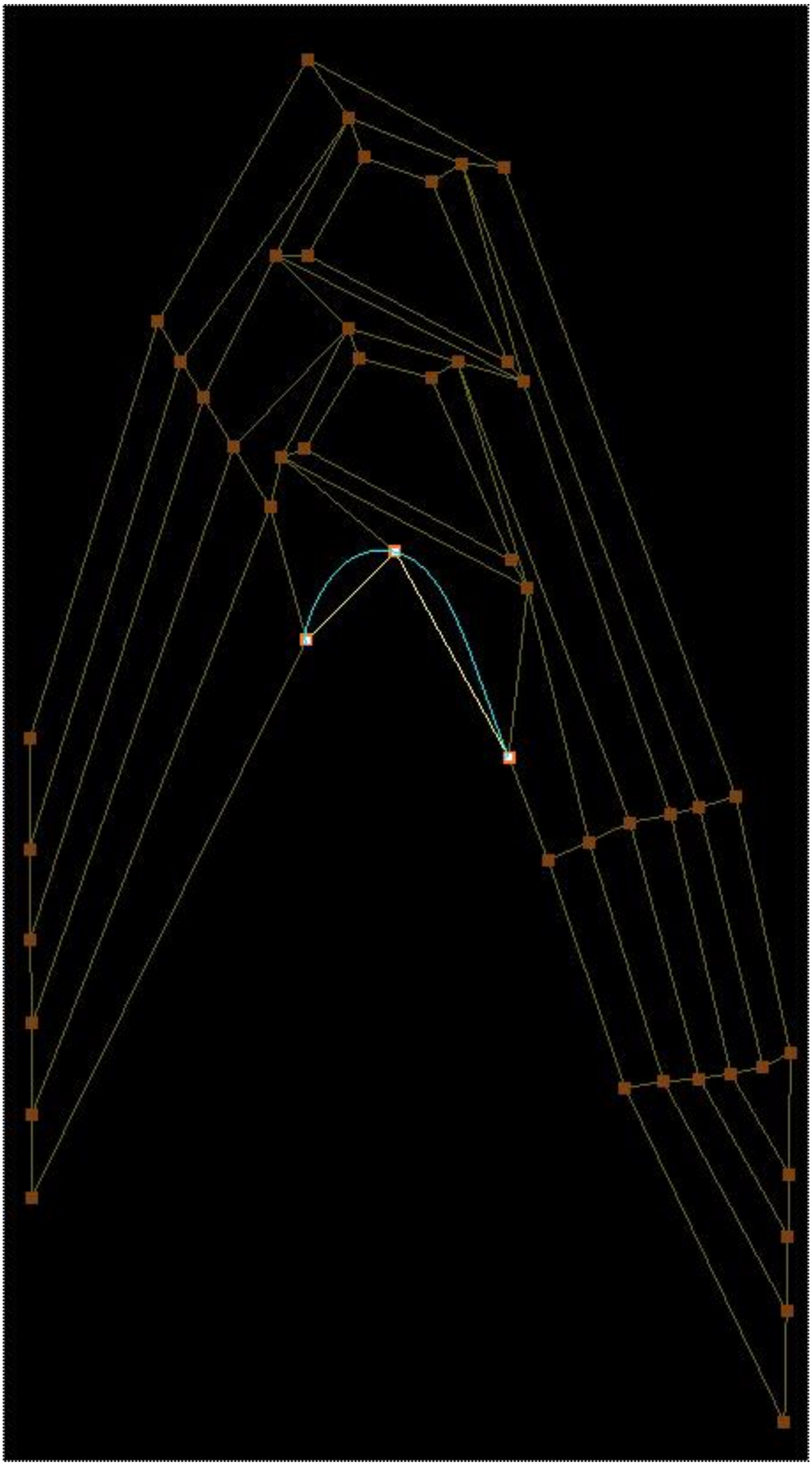


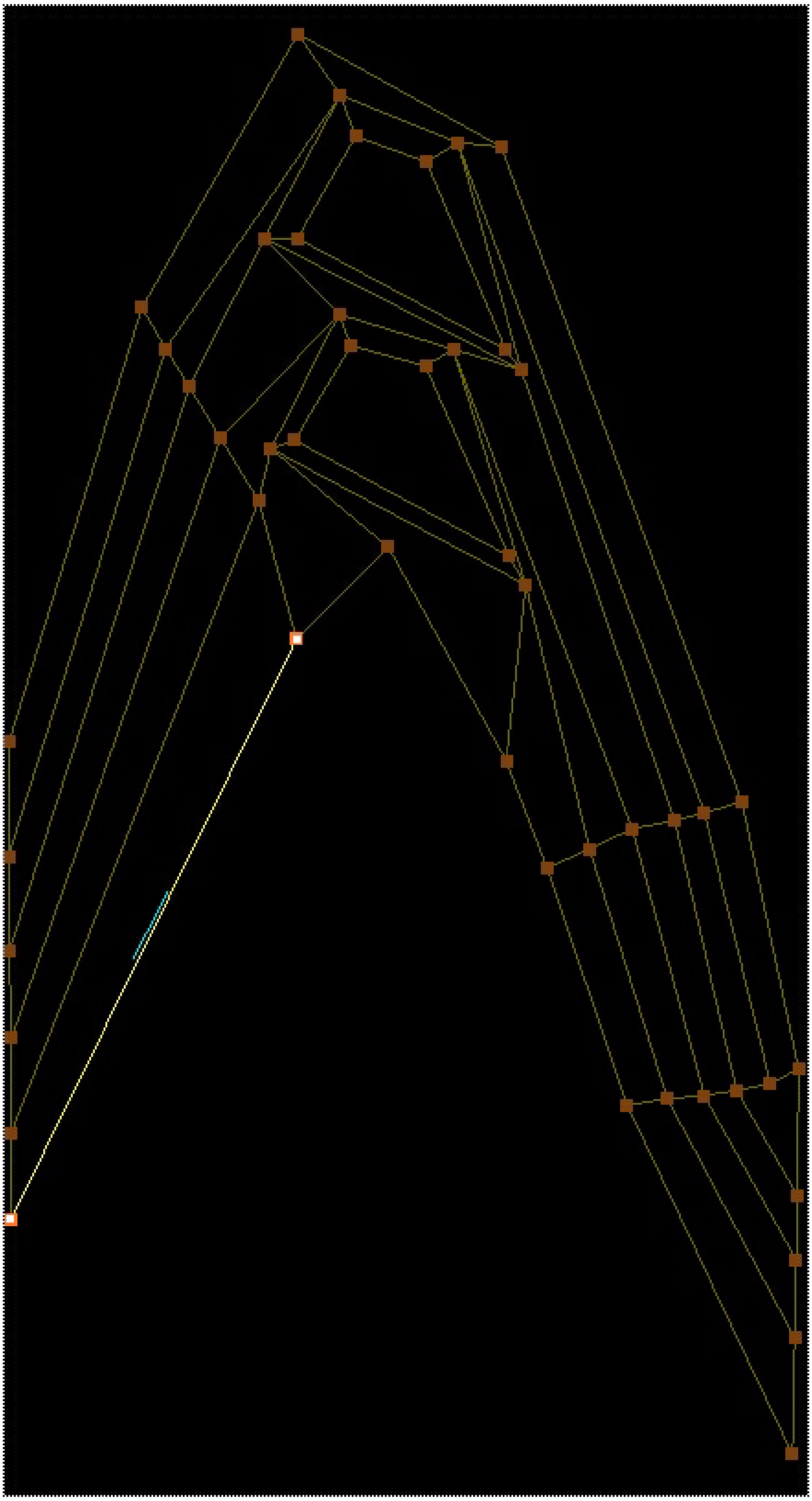


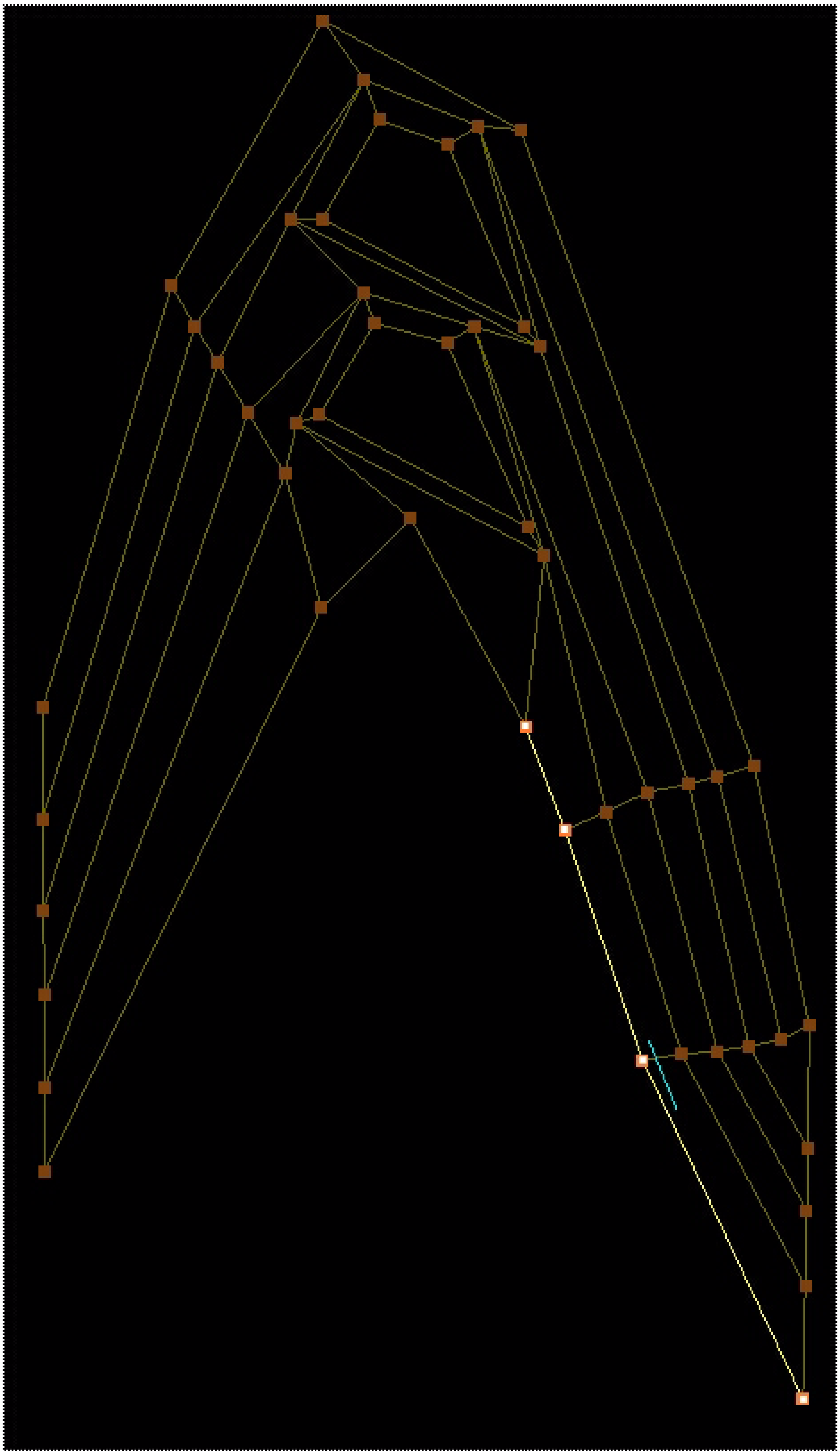


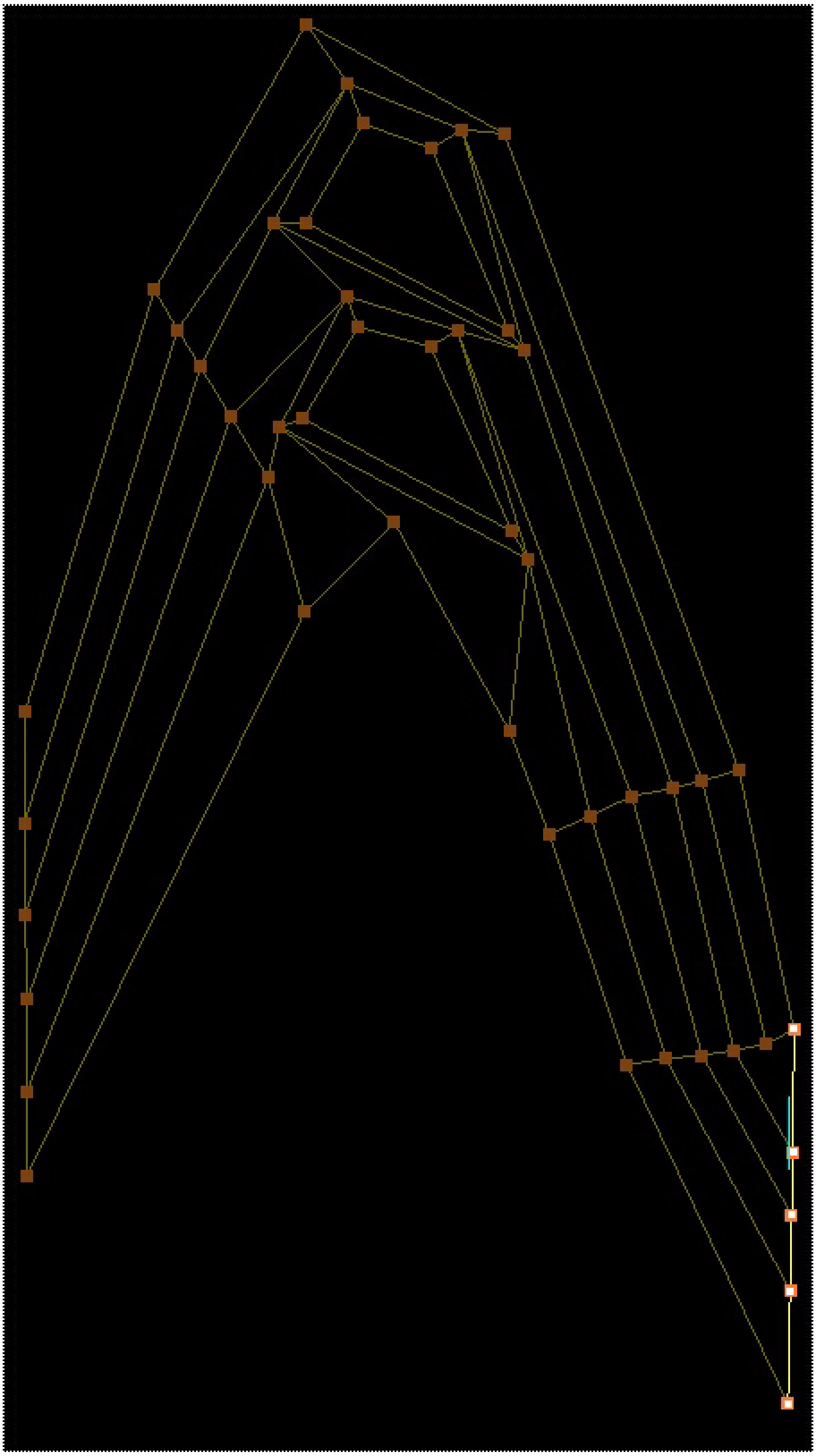


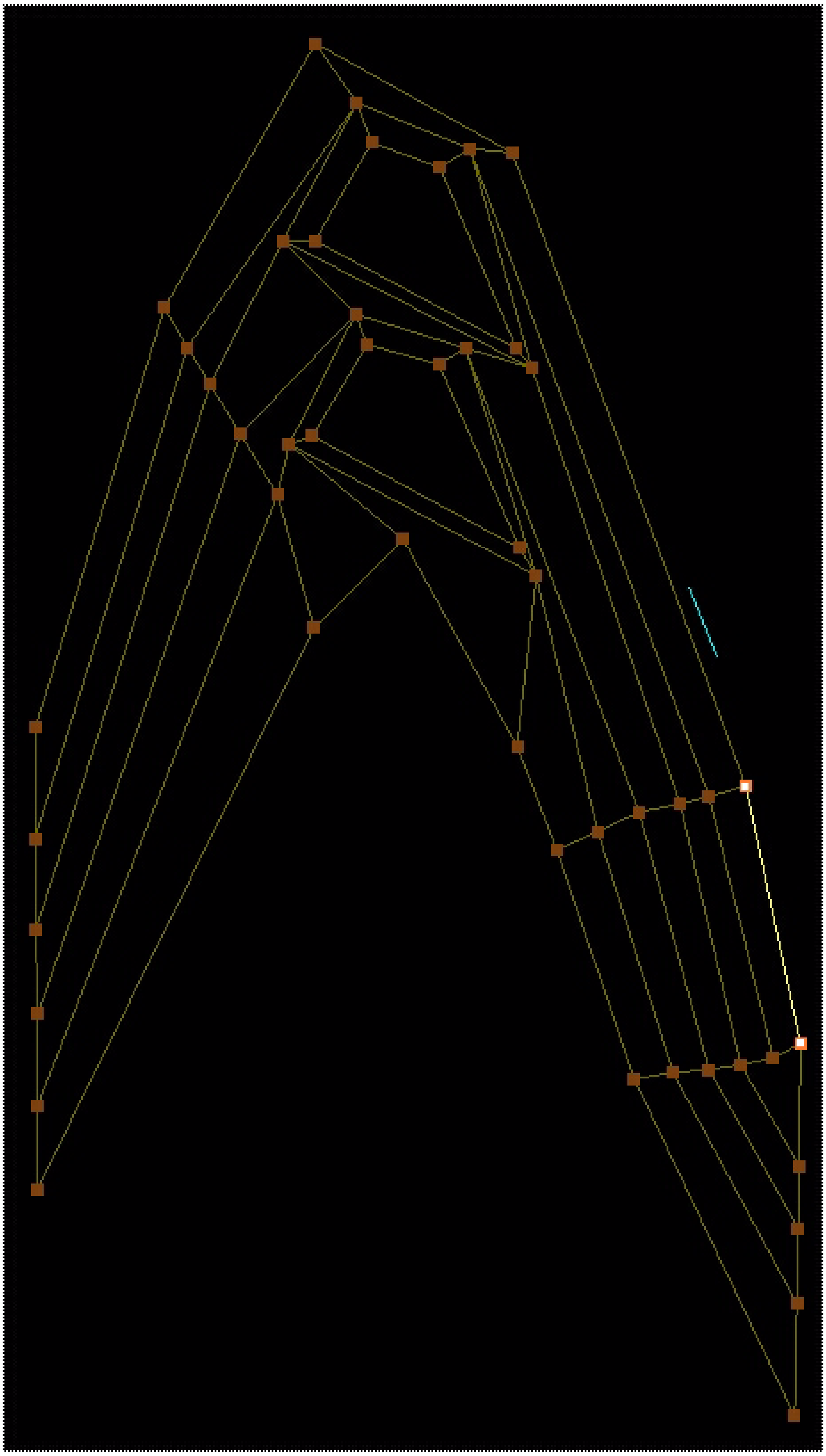






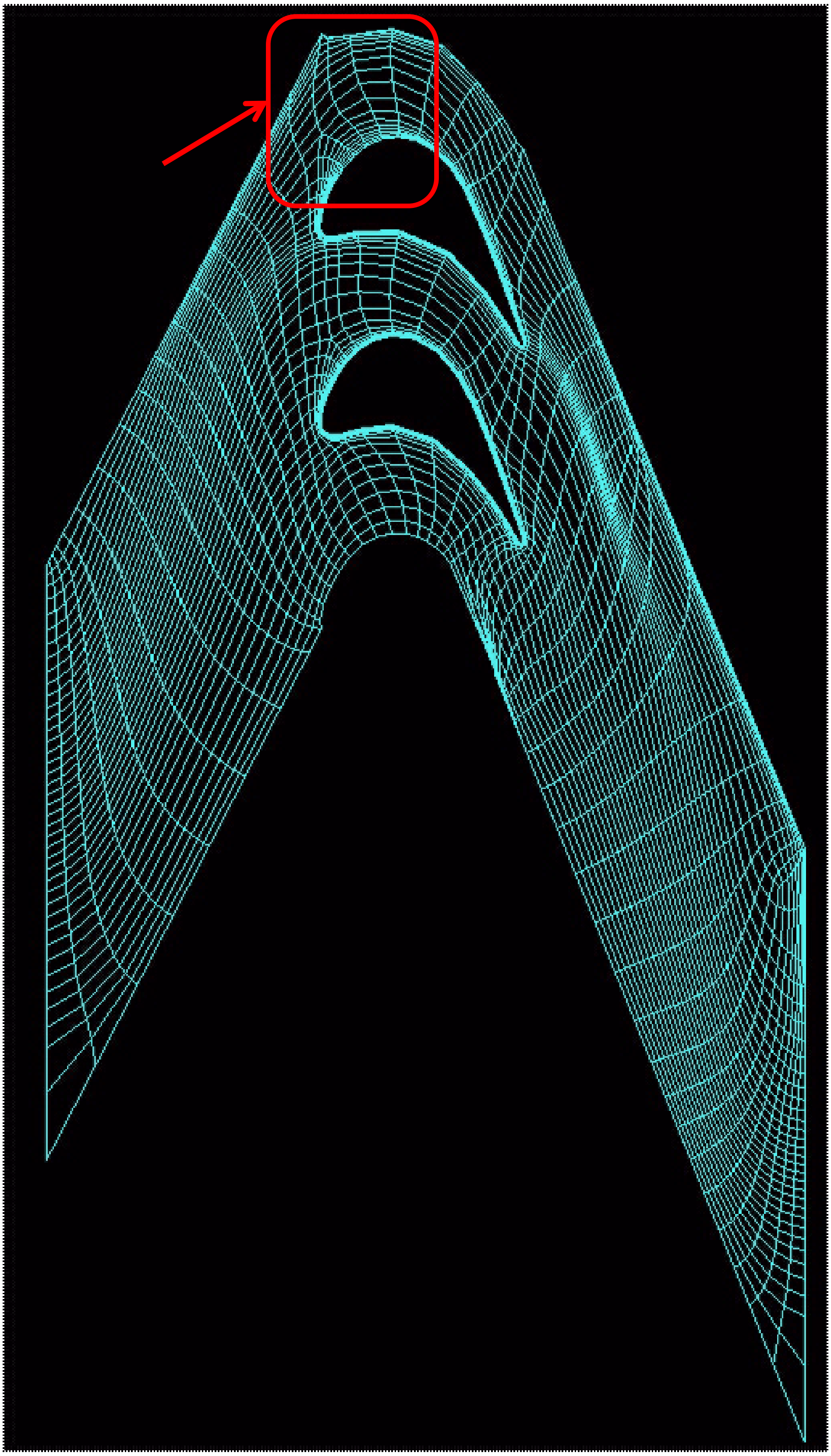




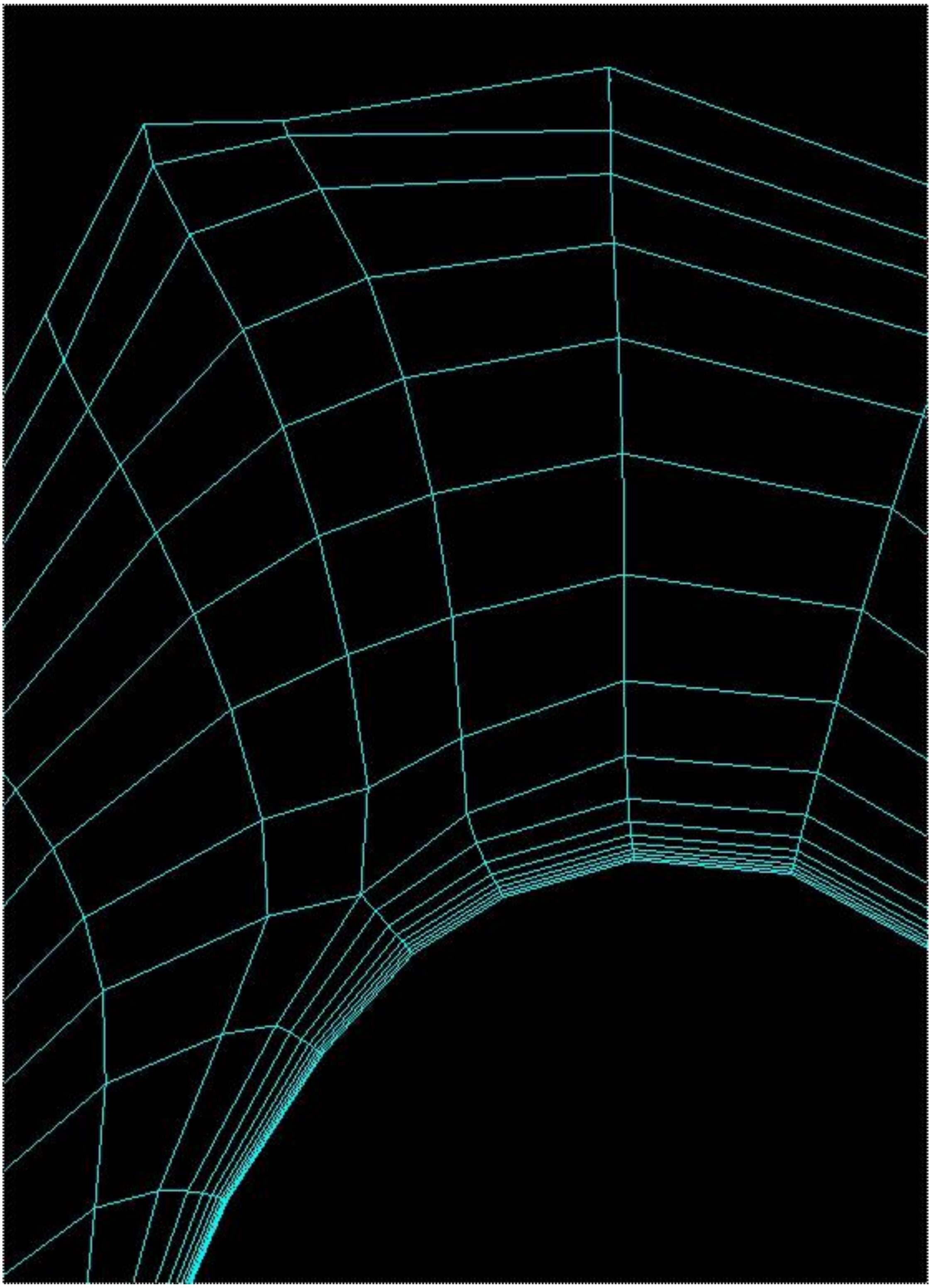


The grid you create will look like this.

GRID



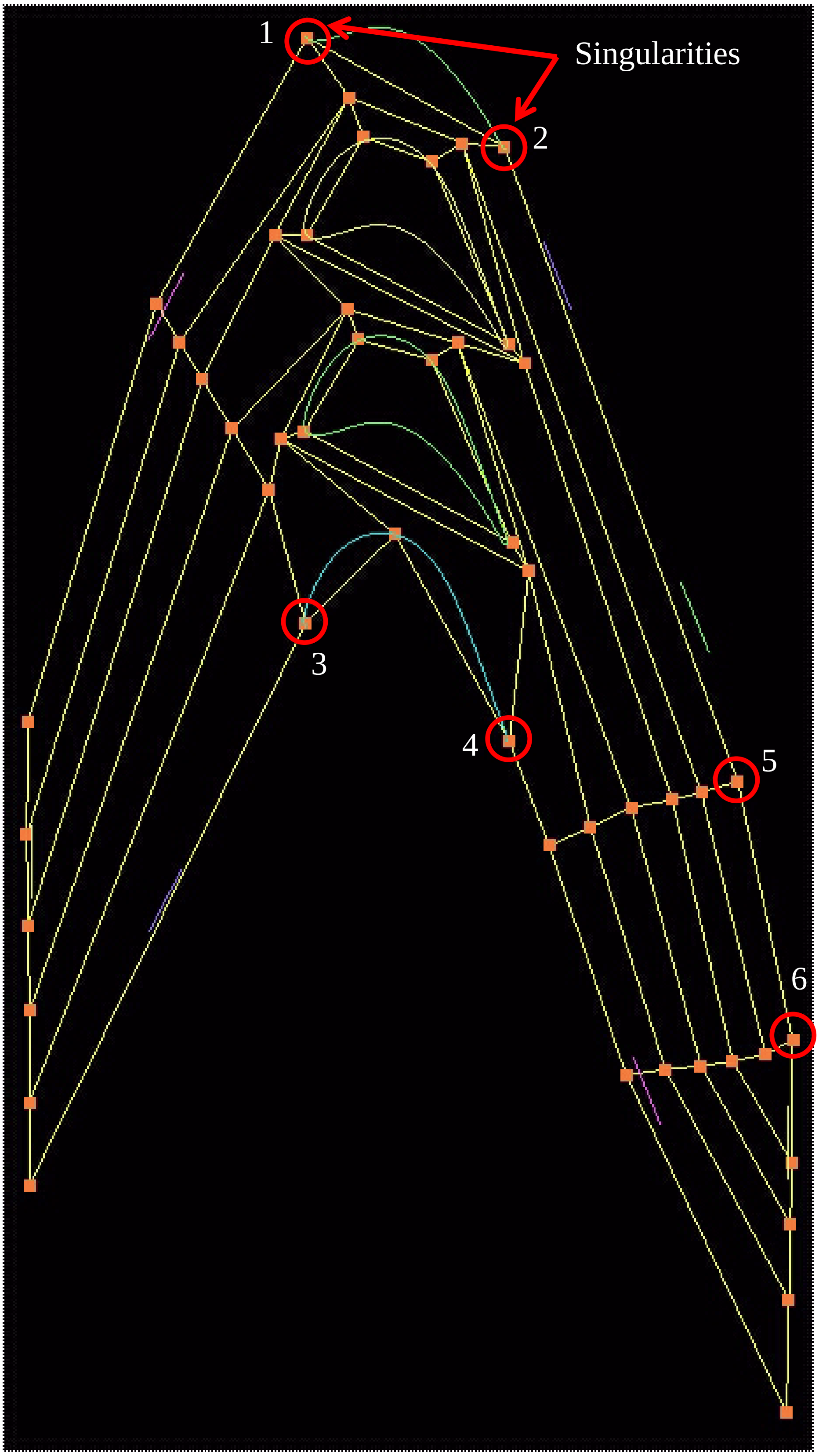
A closer look at the corner region shows a defect in the grid.



This defect is because of the singularity which we were warned of.

Step 3 Splitting corners to avoid the singularity

Now, let’s go back to the **topology builder** and see what the singularity is all about.



There are 6 singularities as shown above. This is because we are having two blocks at the intersection of two surfaces, a singularity which generally creates a bad grid. Lets take a closer look at the singularity marked **1** figure above.

To avoid this singularity, you can split the corner point into two as shown below.

First remove the corner marked by red as shown below. The insert two new corners using the **I** key at the places shown in green. After this connect these two edges to the corner using the **r-lk** button.

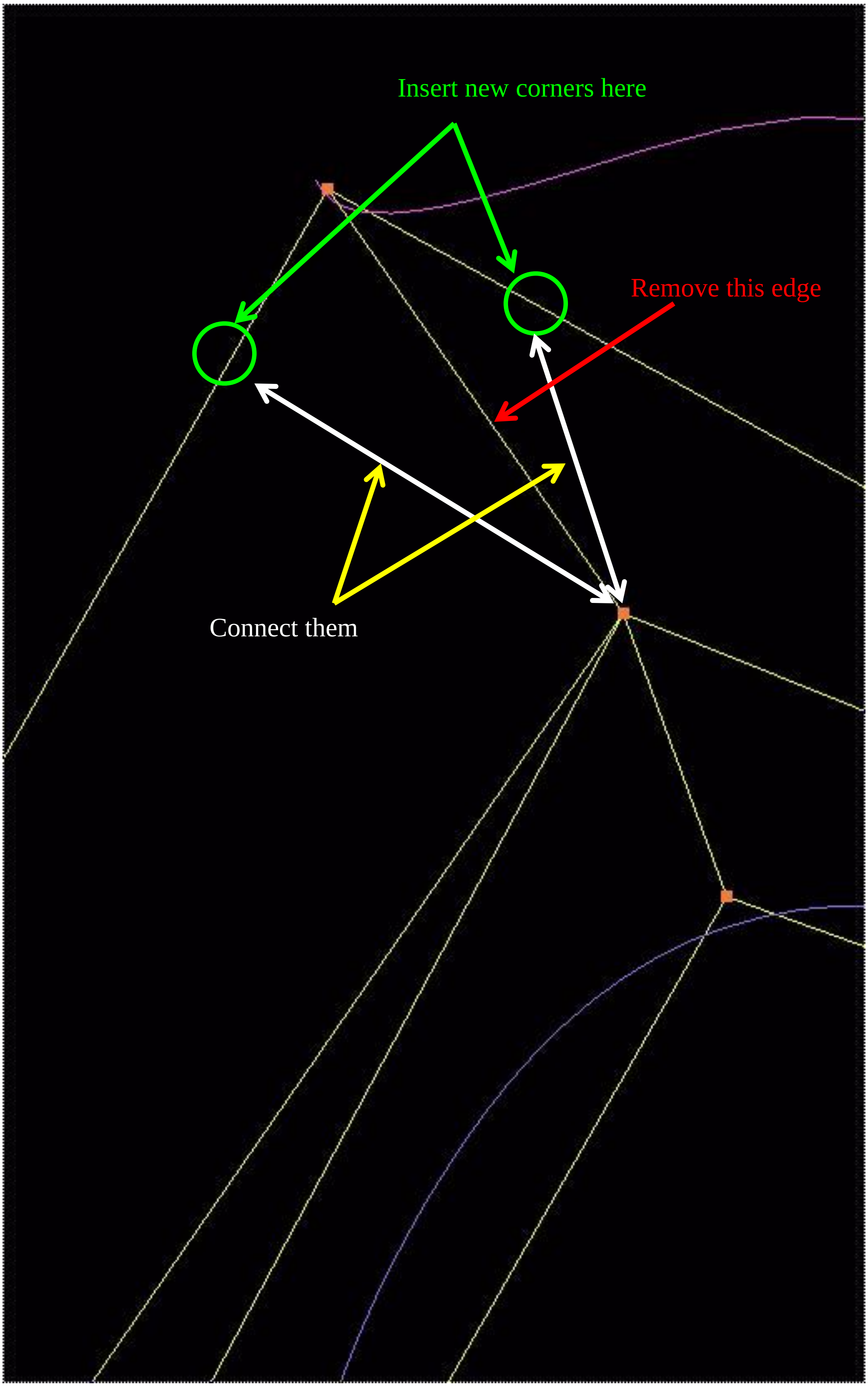
Another use of the r-lk button

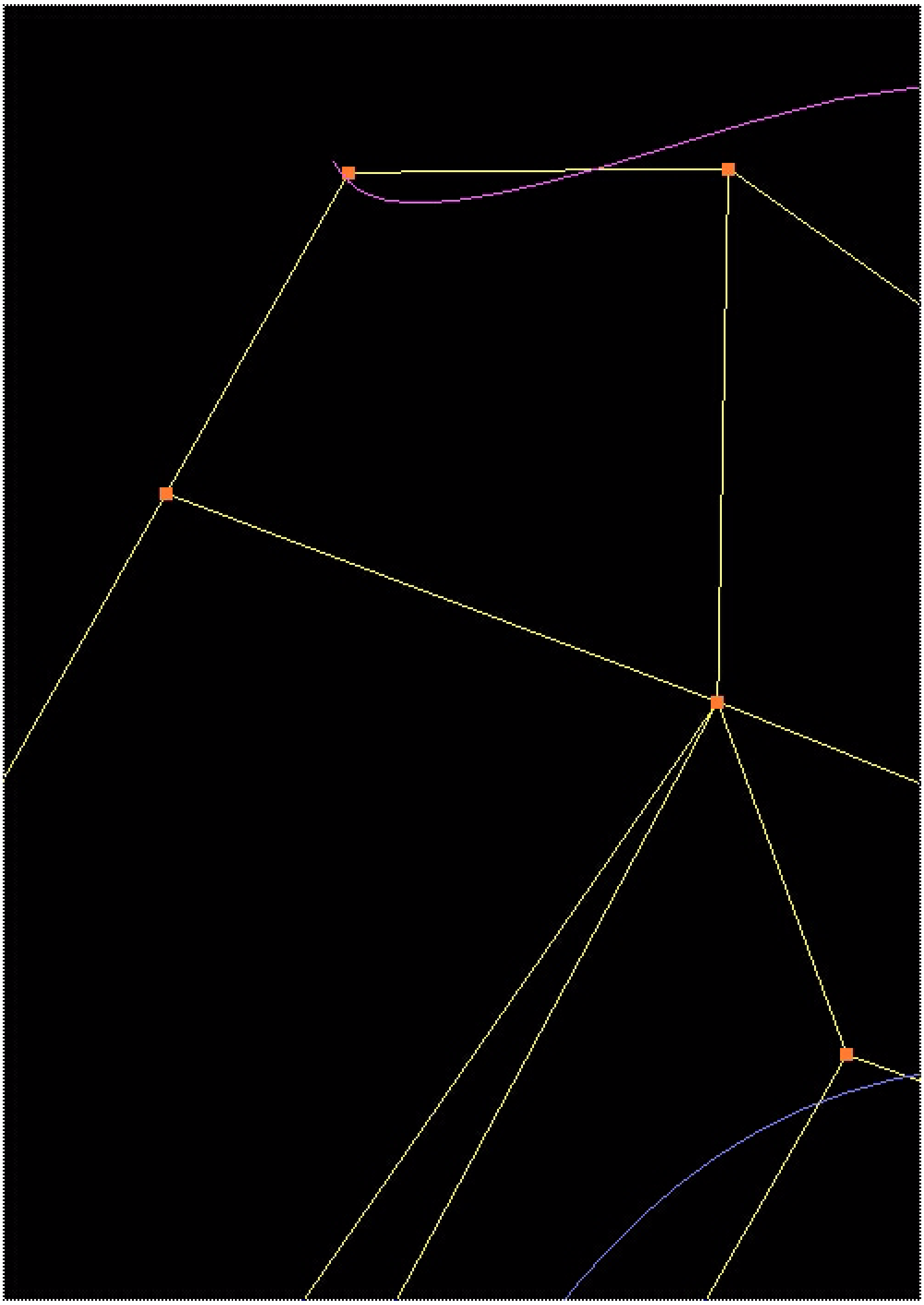
This is one more way you can use the **r-lk** but-ton. Press the **r-lk** button, and then drag a box using the **right** mouse button around the corner marked 1 first. Then, drag a box using the right mouse button on the corners you wanted them to be connected to (marked 3), and you will get them linked.

Splitting corners like this is a technique which you can use in a lot of places. As you will see, we will also be using this to avoid some more singularities as they pop up.

Also, note that you do not have to do the surface assignments again. The surface assignments you did before was good enough, and GridPro uses the inheritance properties to assign the newly inserted corners to the appropriate surface.

Splitting the corner to avoid a singularity



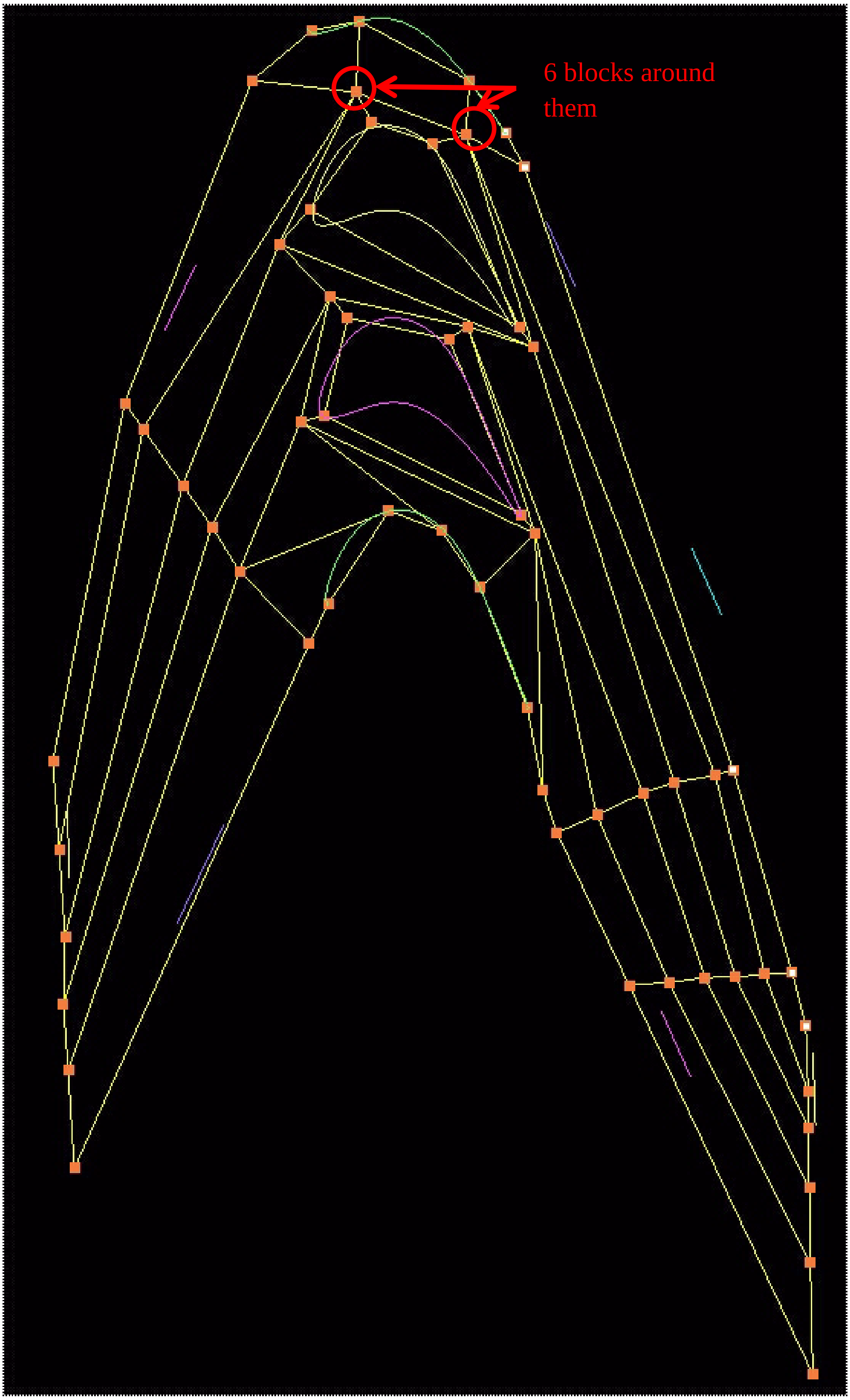


The Split Corner

Similarly, split the corners in all the singularities in the topology. The resulting topology will look like the one below.

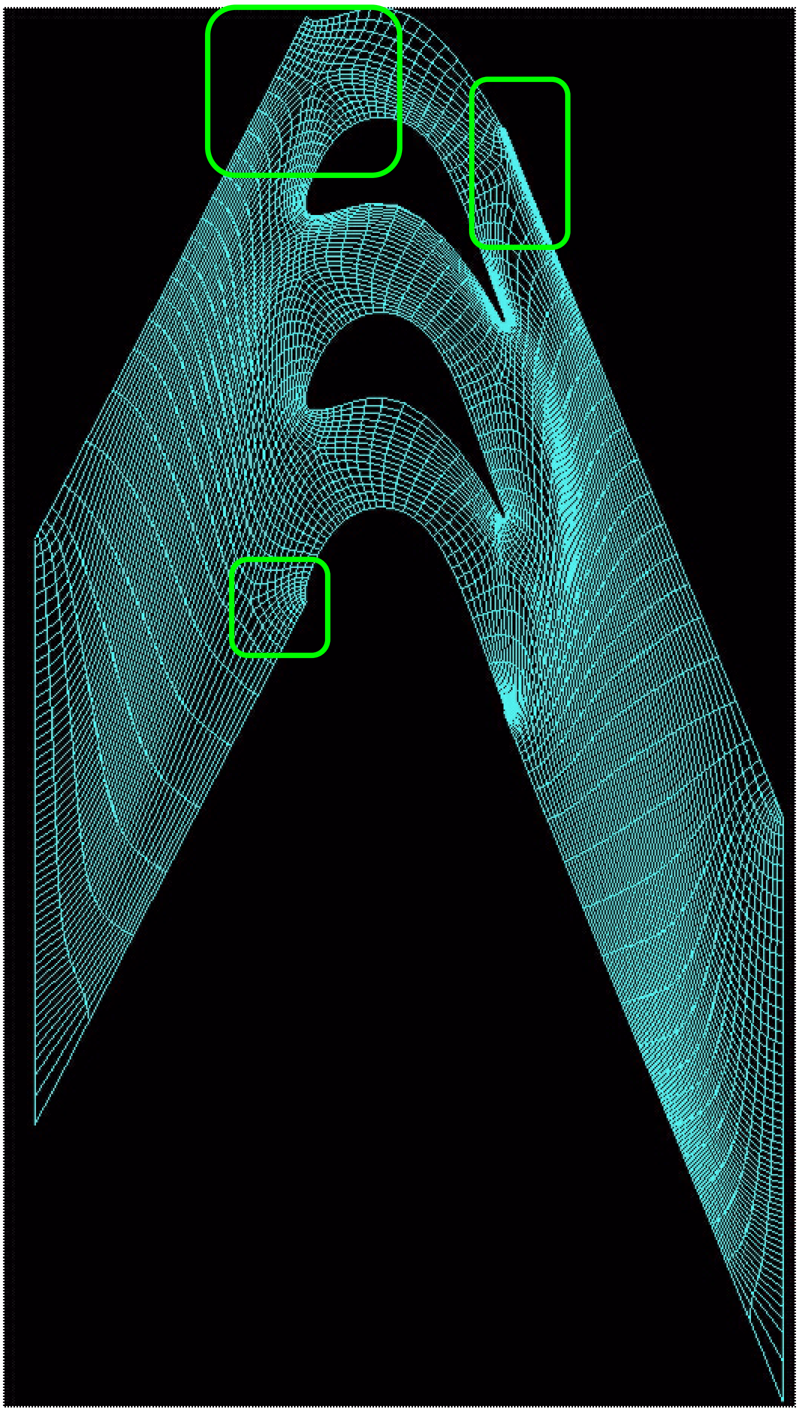
The singularity number 5 has not been split. Singularities are not always as sinister as they may sound. In this case, this singulairty does not do any harm, so you can let it be. A simple way to avoid singularity 5 is to avoid using on of the planes on that side. This will involve changing the surface assignments, and can be done quite easily.

Split Corners to avoid singularities

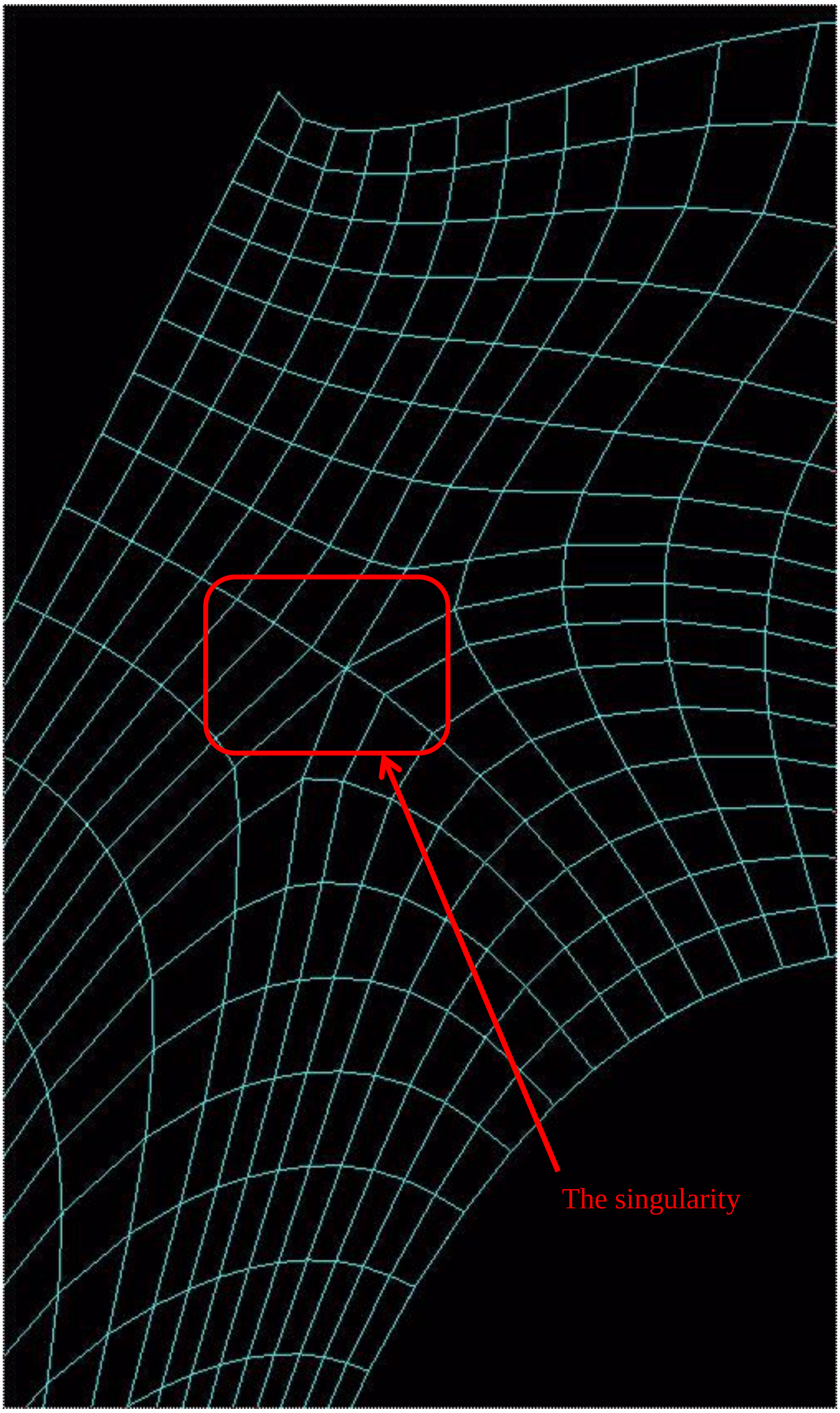


Points have been moved around to make the topology conform to the geometry in the above figure.

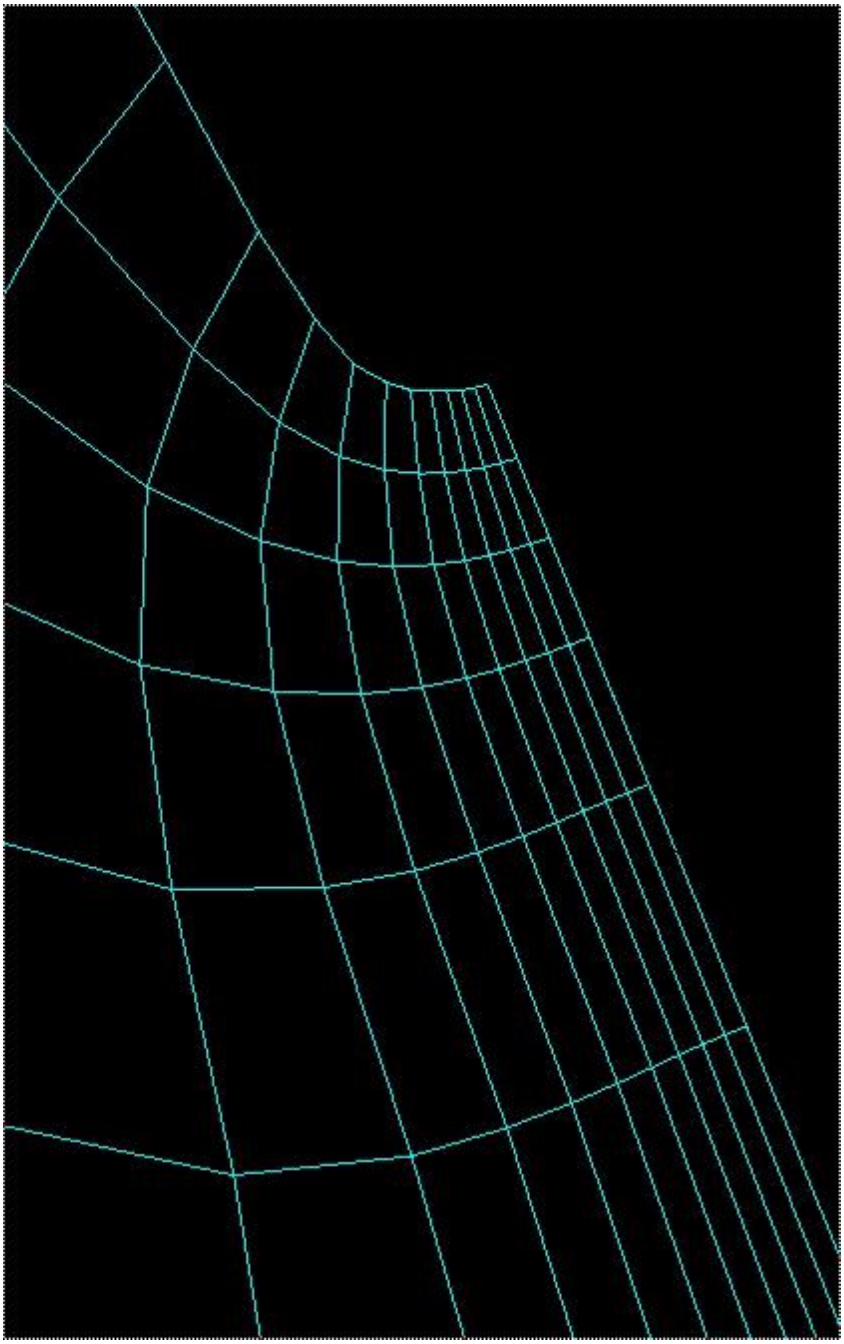
Now, start the gridding process. You will not get any warning, but if you do look closely, there is a bad singularity in this topology too. It is marked in the above figure. Note that the marked corner has six blocks sorrunding it.



The grid after spliting the corner points

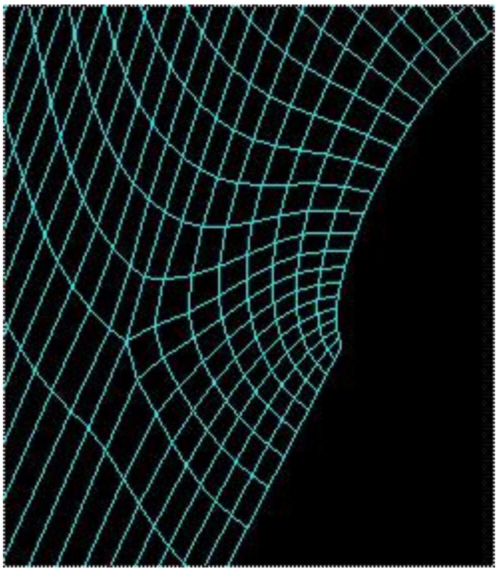


A closer look at a corner



As you see, the difference in quality of the grid is quite pronounced at the corners.

Compare these two grids to understand what you have achieved by splitting the corner points. Also, try to figure out a way to split the singular 6 block point and make the grid free of singularities. It will be shown in the next section anyway, but it will be good practise if you can do it yourself.



Another corner point

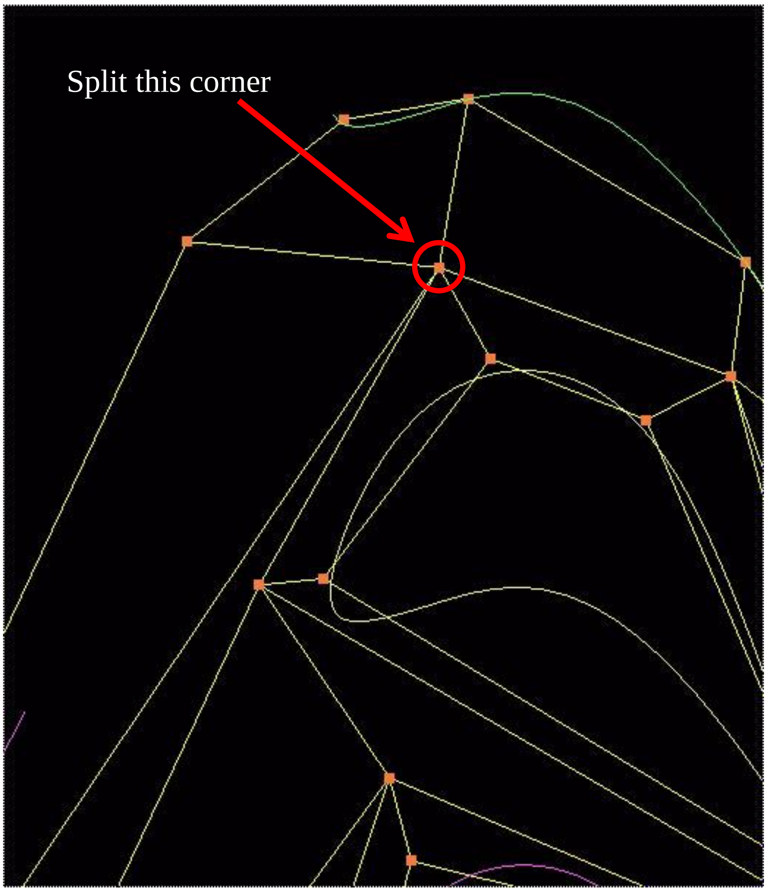
Step 4 Avoiding the six point singularity

You had made the first correction and improved the quality of the grid near the corners. But by splitting corners, you had added more connections to some points and as a result, they now have 6 blocks sorrounding them. This is a bad singularity.

Security of n-point singularities

An **n-point singularity** is when a point has n (not equal to 4) blocks surrounding it. The security of n-point singularities is measured by its departure from 4, a number which is called the valence. For valence 1, there are either 3 or 5 blocks surrounding the corner (or edge in 3d). Usually, a departure of more than one is considered a bad valence for the grid. The angle surrounding a point is 360, and when there are 4 blocks around it, the angle can be split into 90 each, leading to a nice orthogonal grid. Departures from this will lead to more skewed angles, and such departures should be avoided when-ever possible.

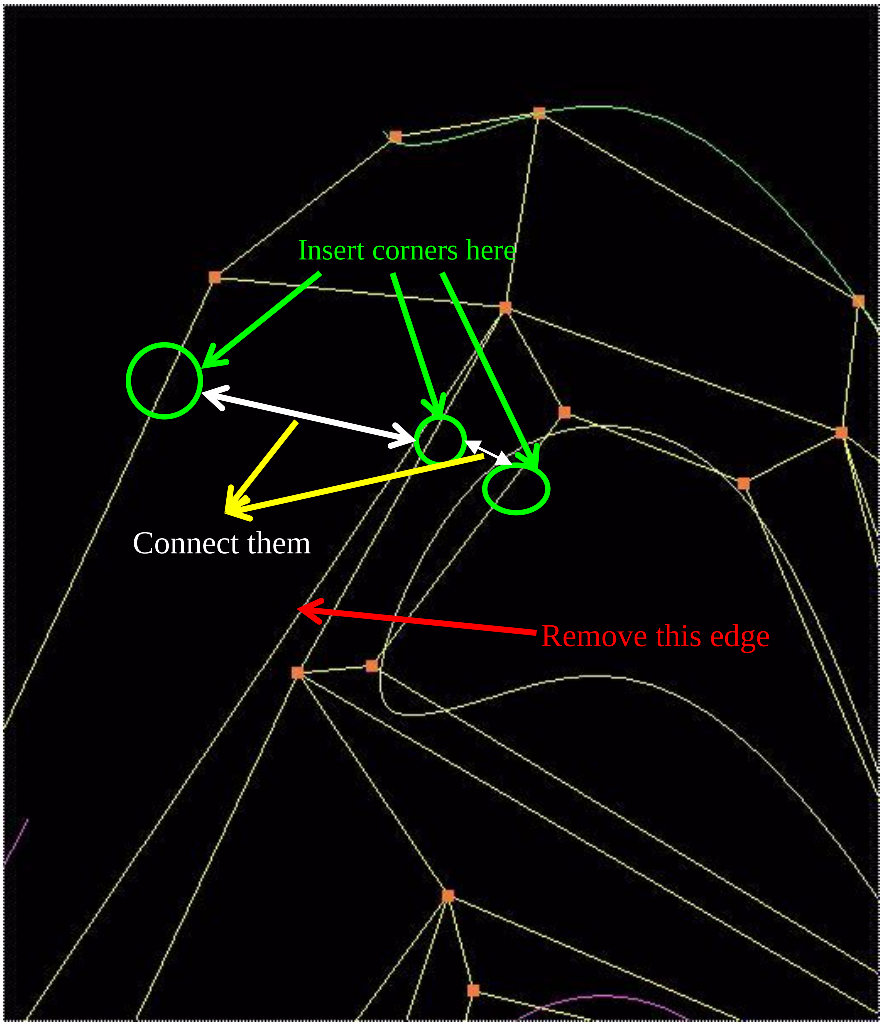
We can avoid this singulaity by the same technique used in the previous section - by splitting corners.



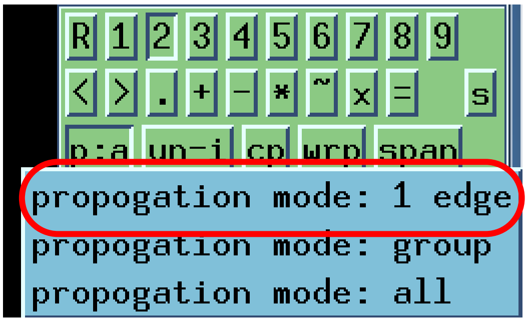
To split this corner, first remove the edge shown in red in the picture below. Insert at the place marked **1** in the picture below. Before you insert at the places marked **2** and **3**, you will have to change the insert mode. If you try inserting at the places **2** and **3** without changing the insert mode, you will see that you get unwanted edges everywhere in the topology.

Change the insert option to **mode: 1 edge insert** by clicking on the **i:a** button in the TOPO panel as shown below.

Now, connect the three new corners you have created.

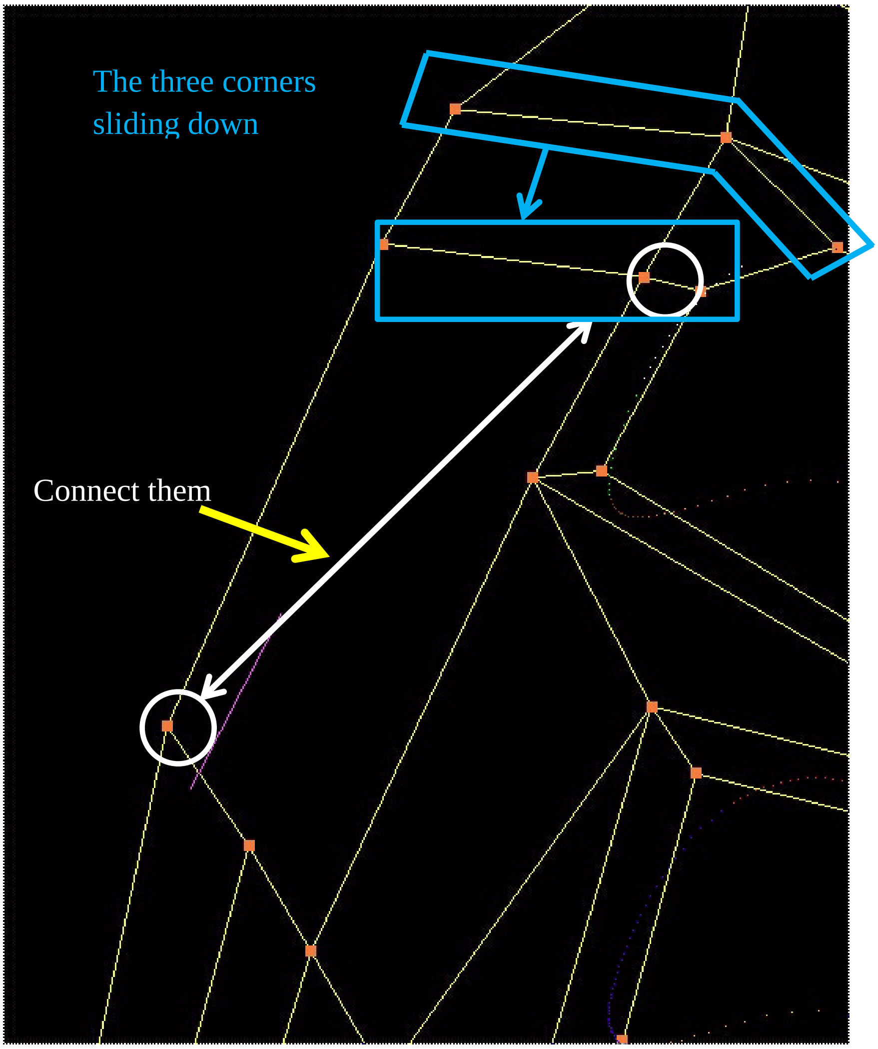


Splitting the Corner

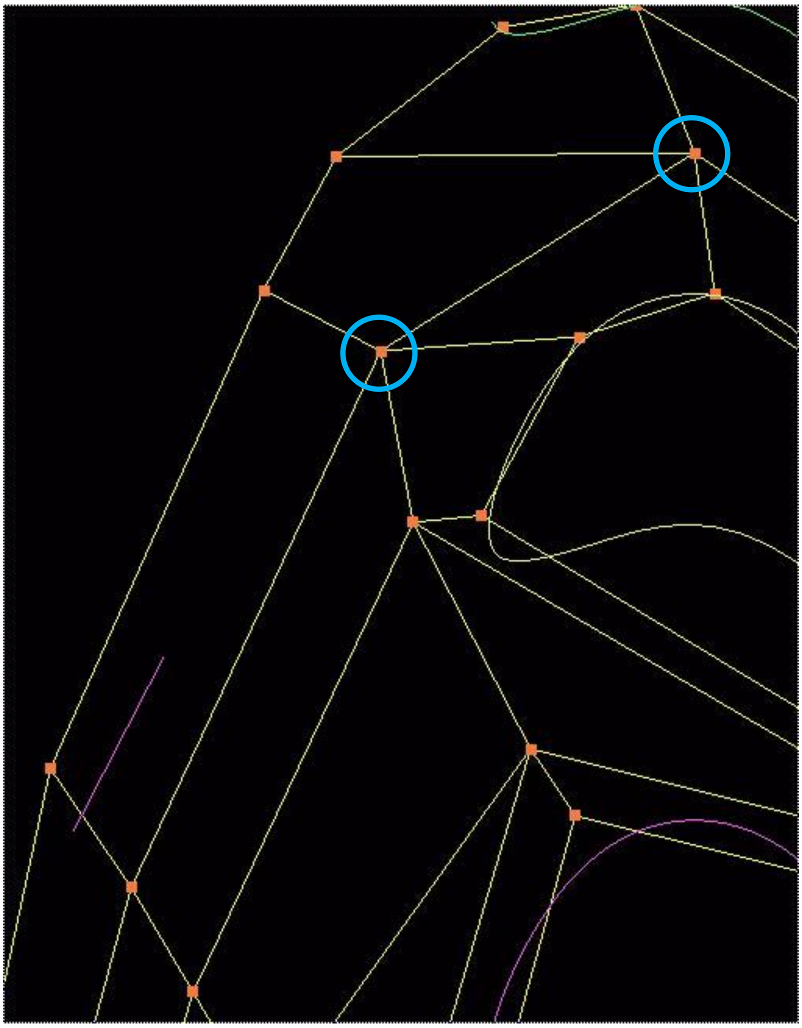


Insert Mode

Let's have a look at what has been done. Note that you had actually split all the three corners by doing the above actions and got them sliding down as shown in the figure below.

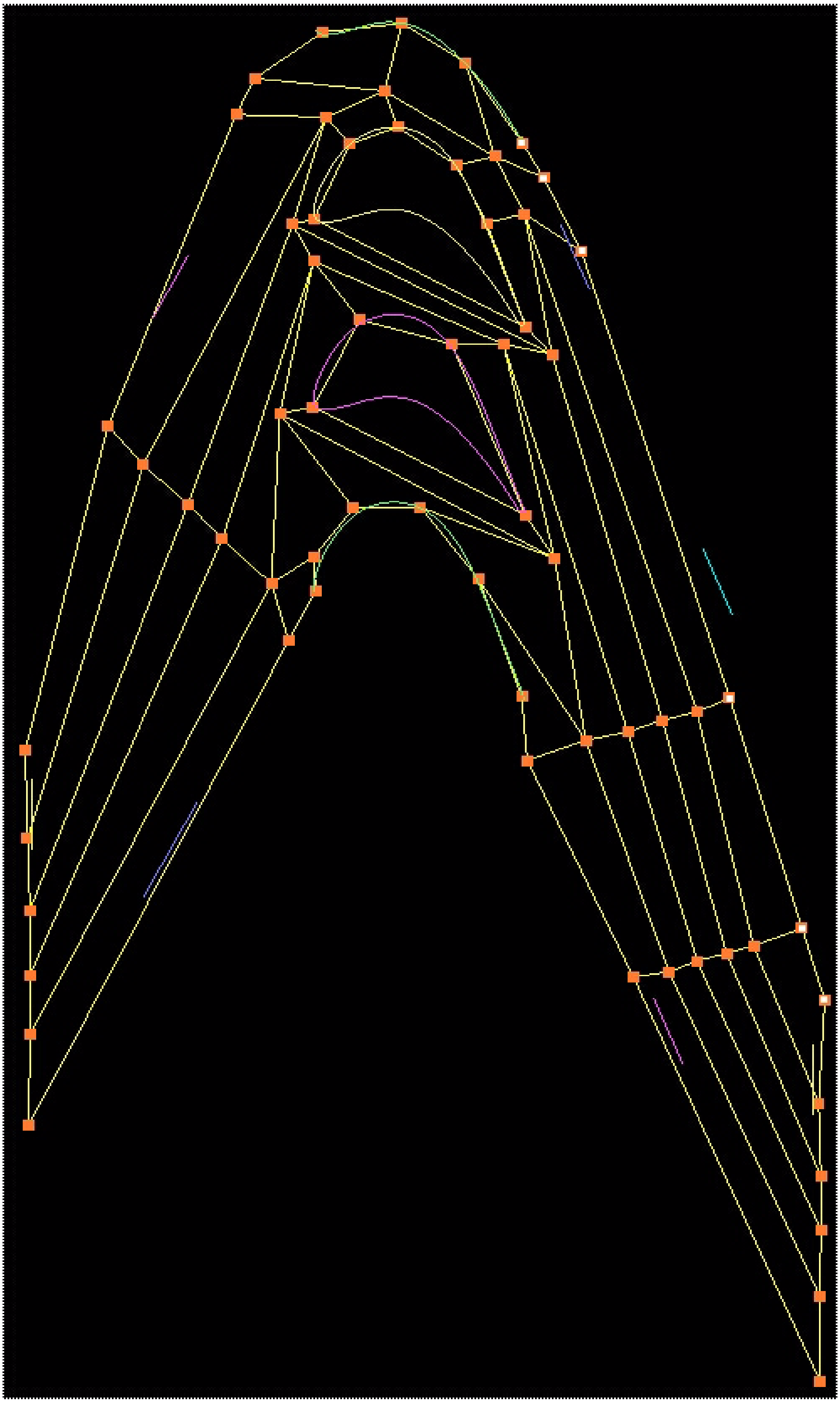


To restore the original connection which had been broken, connect the 2 corners as shown in the figure above. This will completly split the 6-point singularity into two 5-point singularities. To topology will then look like this.



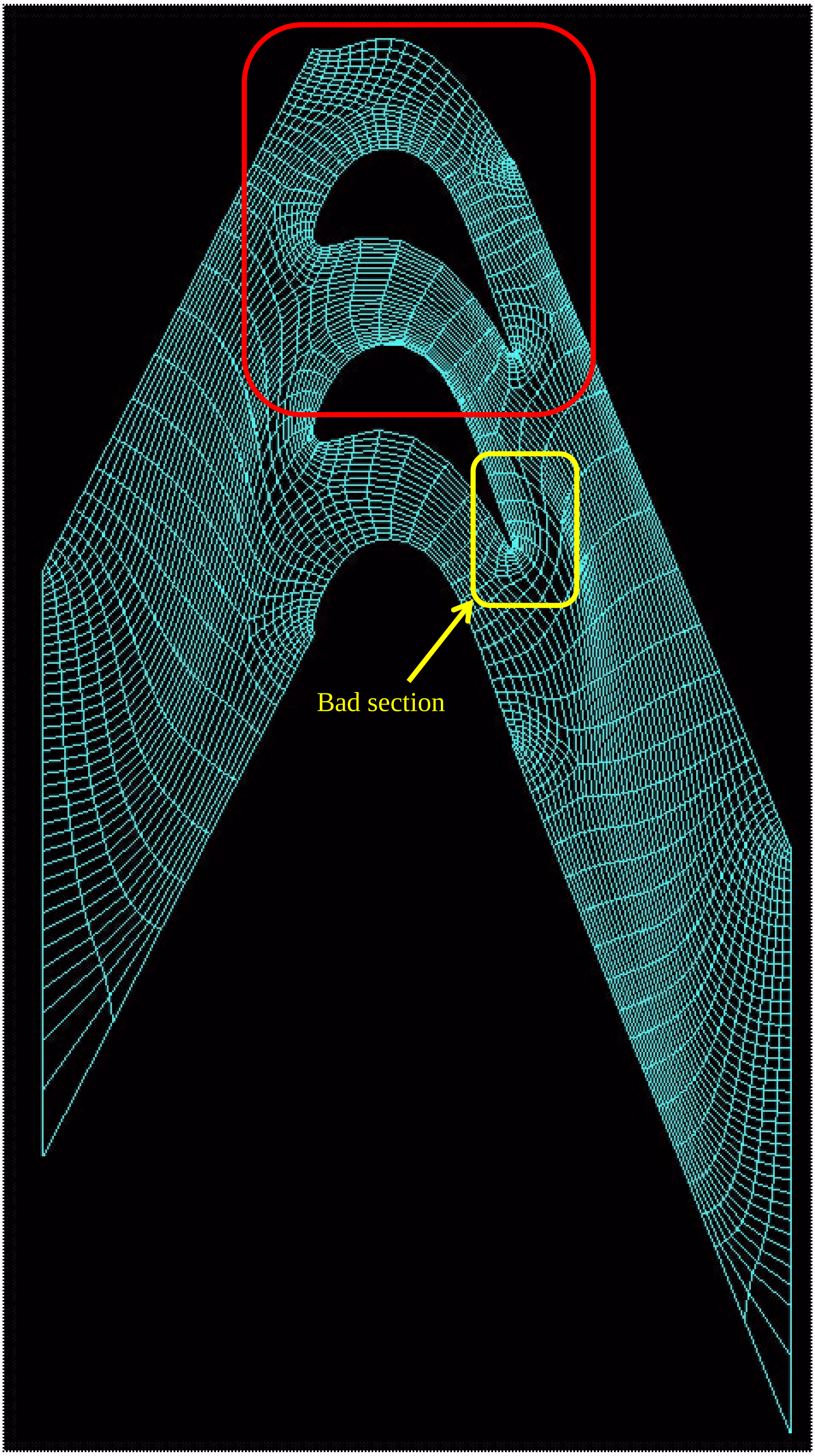
Points have been moved around in the above figure to make the topology look nicer. The 2 daugther corners, which came into existense as a result of the corner division is shown in the above figure. Note that these 2 points have a valence of 1 each.

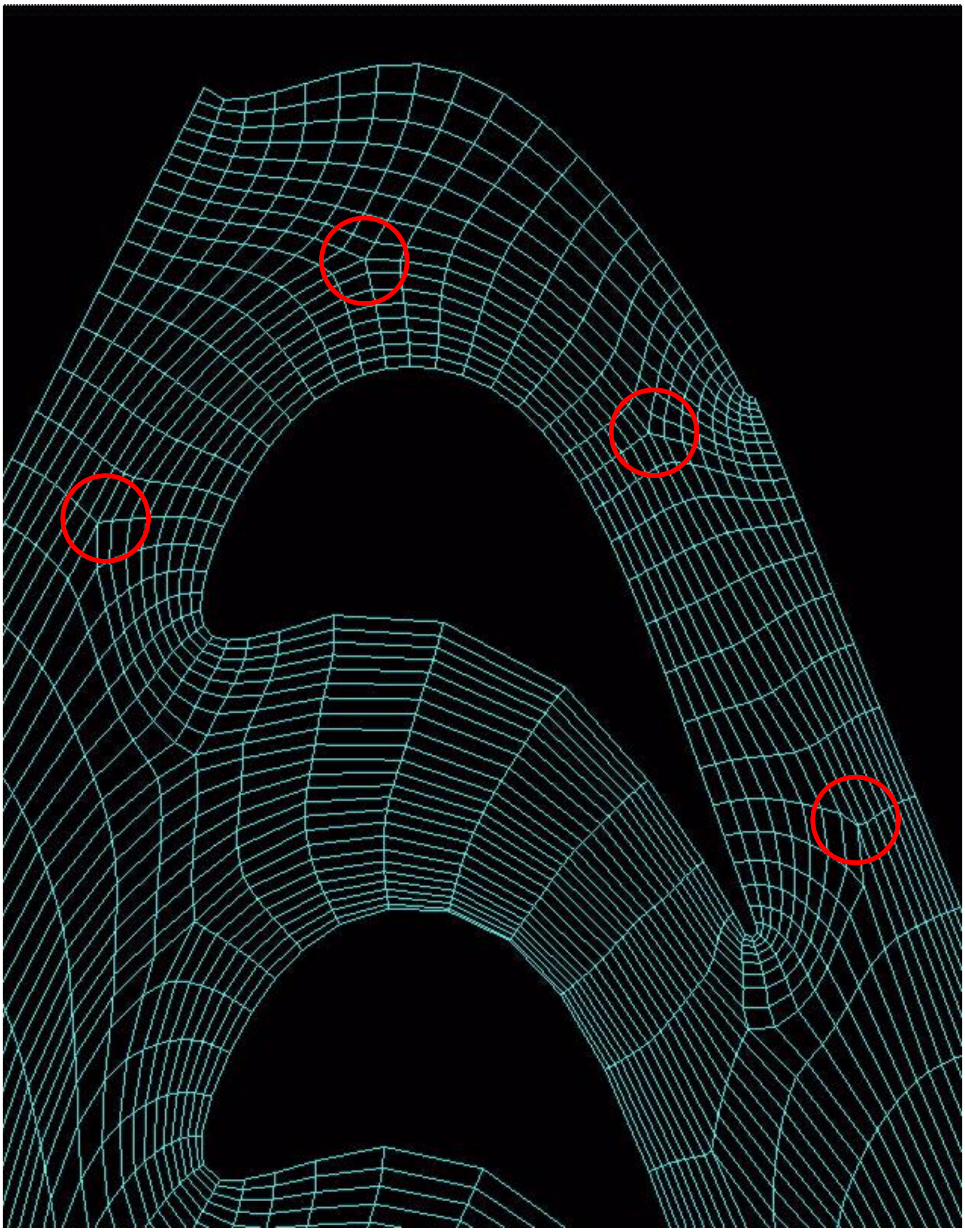
Use this method to split the other 6-point singularity. The resulting topology will look like the one shown below.



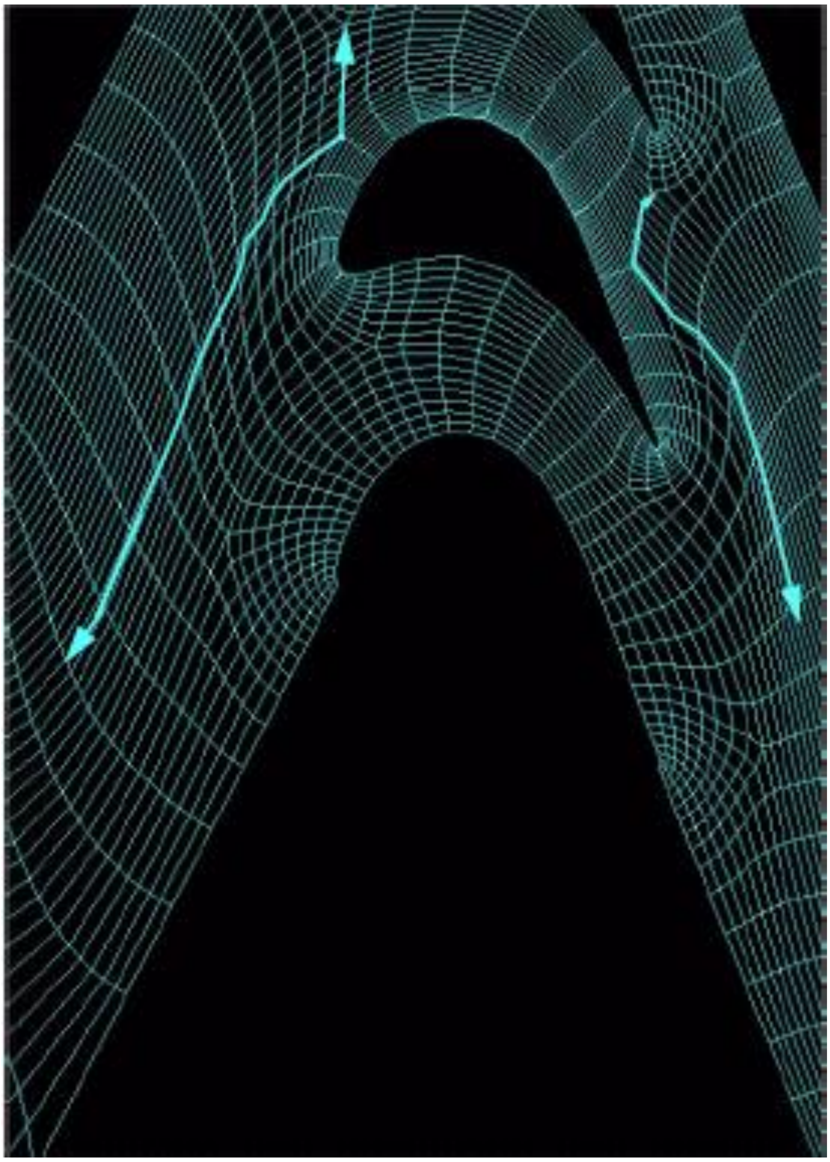
The 6-point singularities removed

Go ahead and start the **Ggrid** for this topology. The resulting grid will look like this.





Note the 5-point singularities in the grid section shown above. The grid looks pretty decent near the corners now. But we are still not satisfied. The grid strectches too much near bottom blade, making it skewed at that place. A bad section which immedeatly catches the eye is marked in the grid.

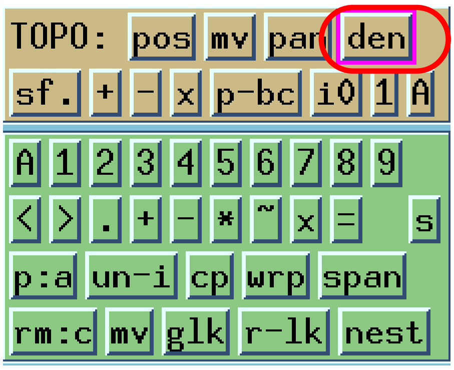


One way to avoid this strecthing is to adjust the density of grid points such that the grid is more even. But even then, you will still notice some stretching. The problem is not with that of grid density, but with that of the flow of grid lines. In this case, the flow of grid lines changes too abruptly, causing the grid to stretch.

Now, we realise a mistake in the topology design. We have to now make some changes to the topology such that the grid lines (shown above), do not change its flow direction so abruptly. We can achieve this by making a part of the grid lines go to the side instead of going down. In the next section, you will make changes in the topology to achieve this.

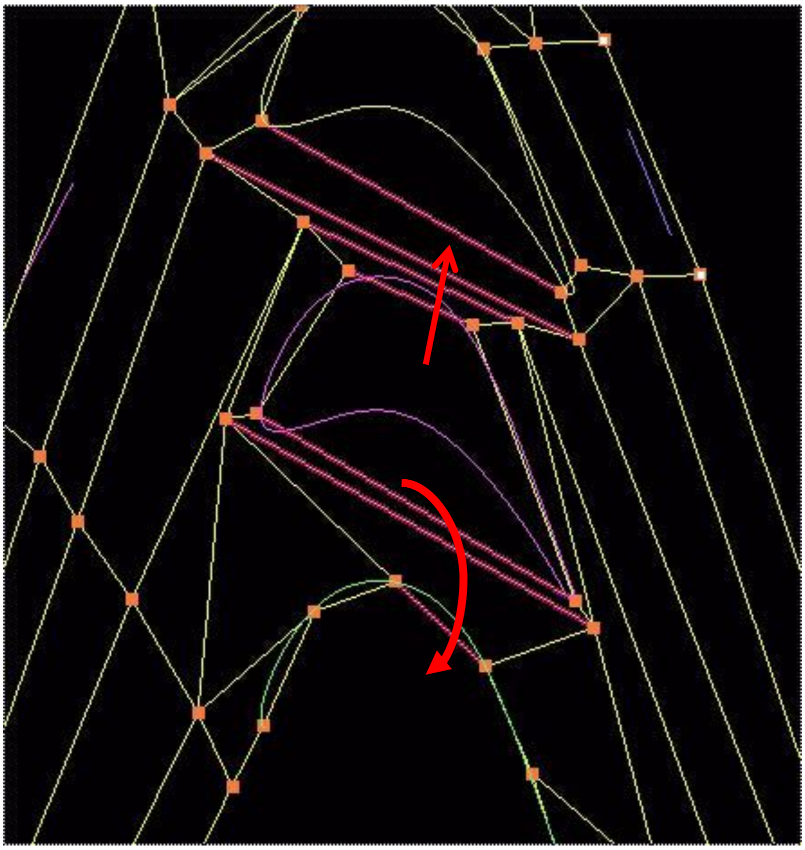
Step 5 Controlling the flow of grid lines

The key to controlling the flow of the grid lines is the topology. Look at the topology we have at hand, and deduce how the grid lines are going to flow from that. The **den** button in the TOPO panel can used to visualize this.



Remember that you had used the density button before to change the density of the grid for certain sections of the grid. This button will now be used to visualize the flow of grid lines. After you click on the den button, simply click on any of the edges to help you see the flow.

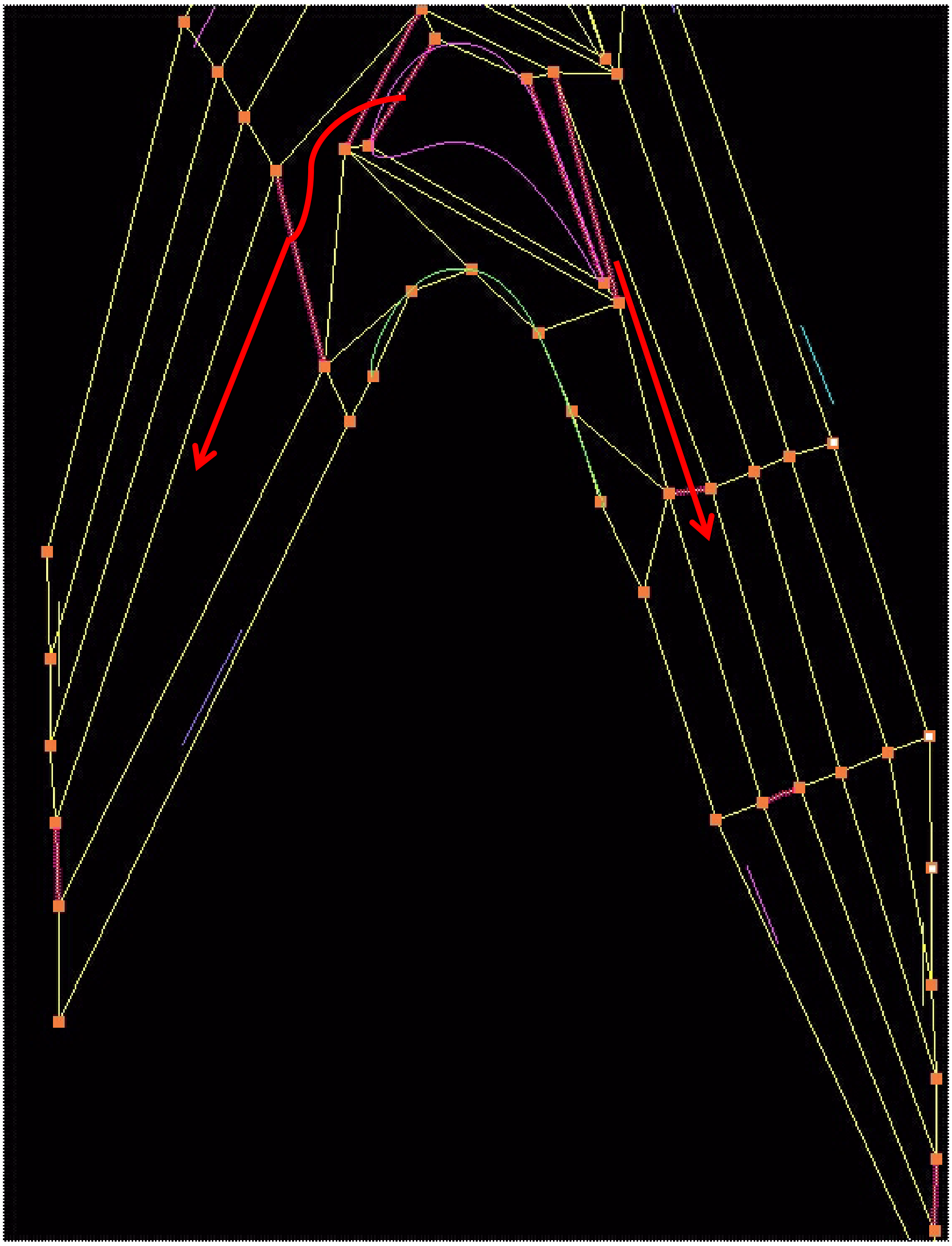
The next few figures will show you the flow of grid lines in the topology we have.



Using den to look at the flow

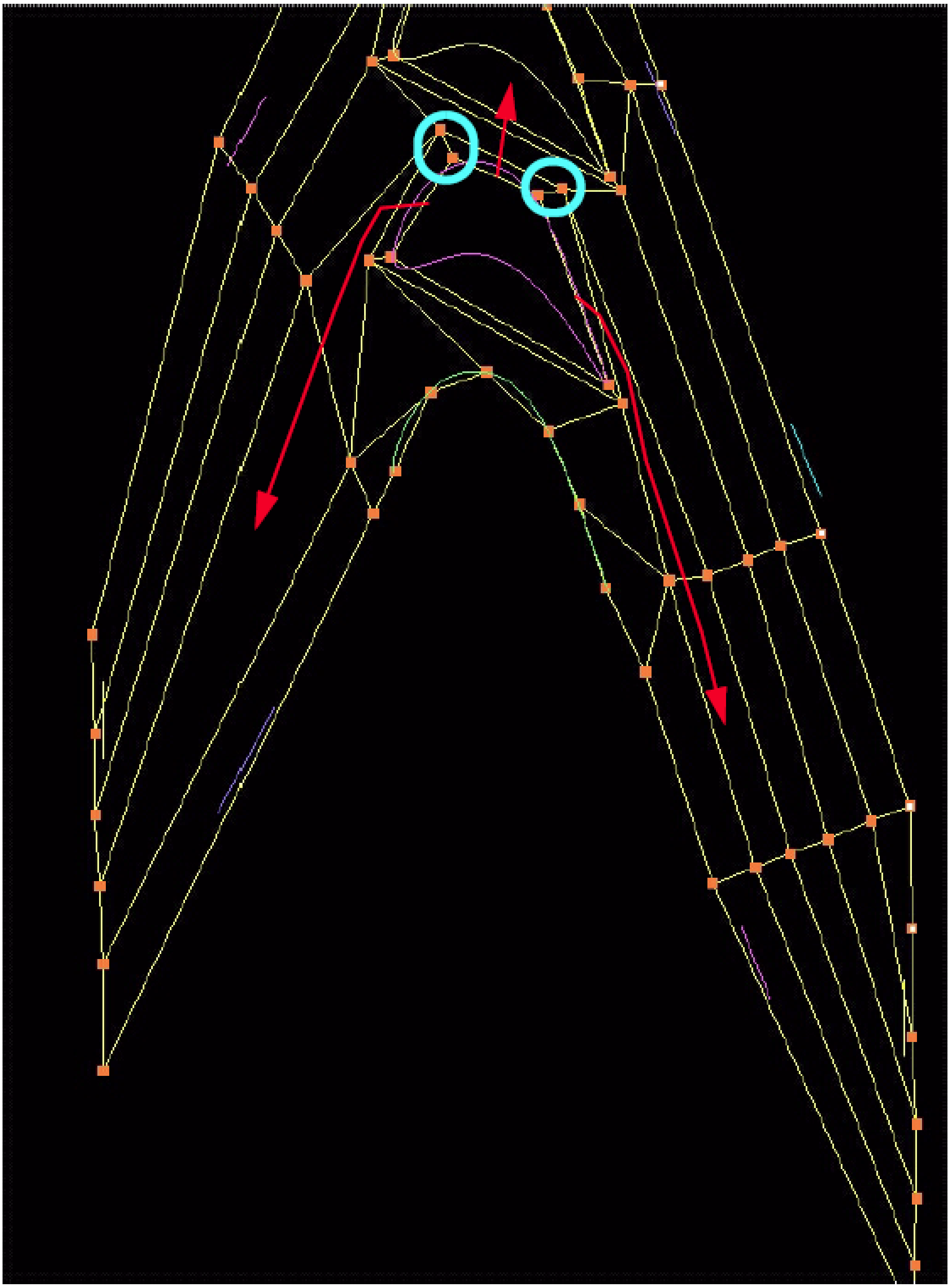
The flow lines have been shown above. After you click **den**, clicking on any of the edges normal to the flow lines will highlight all the edges normal to the flow line. This will help you deduce the flow of the grid lines. In the case shown above, grid lines start from the surface and moves in the direction of the arrows shown in the figure.

Look at the flow in the picture below. Notice that the flow in the figure shown above and the one in the figure shown below are the flows lines in two adjacent blocks. Though these two blocks are adjacent, they have flow lines in opposite diections. This causes the grid to stretch near the intersection of these two blocks. This was responsible for the bad section of the grid generated in the previous section.



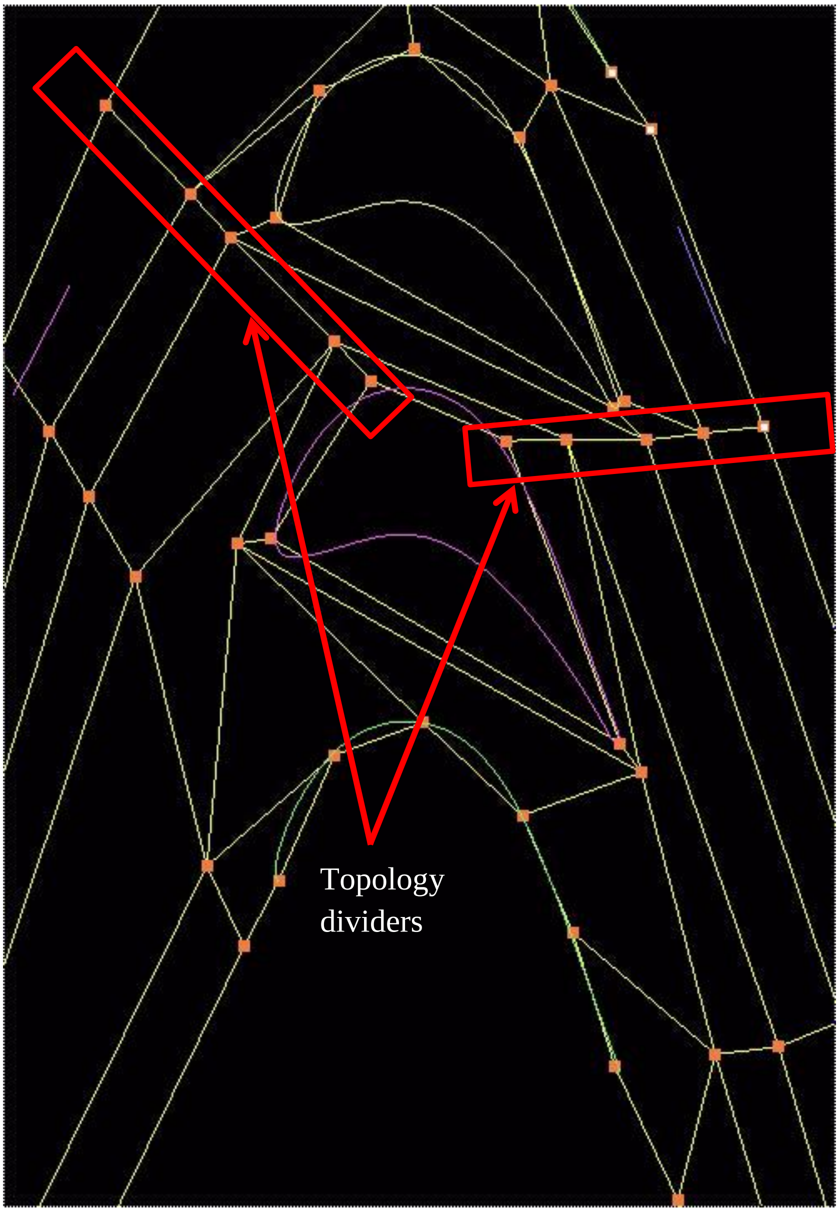
Flow lines for the adjacent blocks

Look at the figure below to get an idea of how the conflicting flows in adjacent blocks can cause grid stretching. Also, note that the flow lines associated with the upper turbine blade changes more gradually.



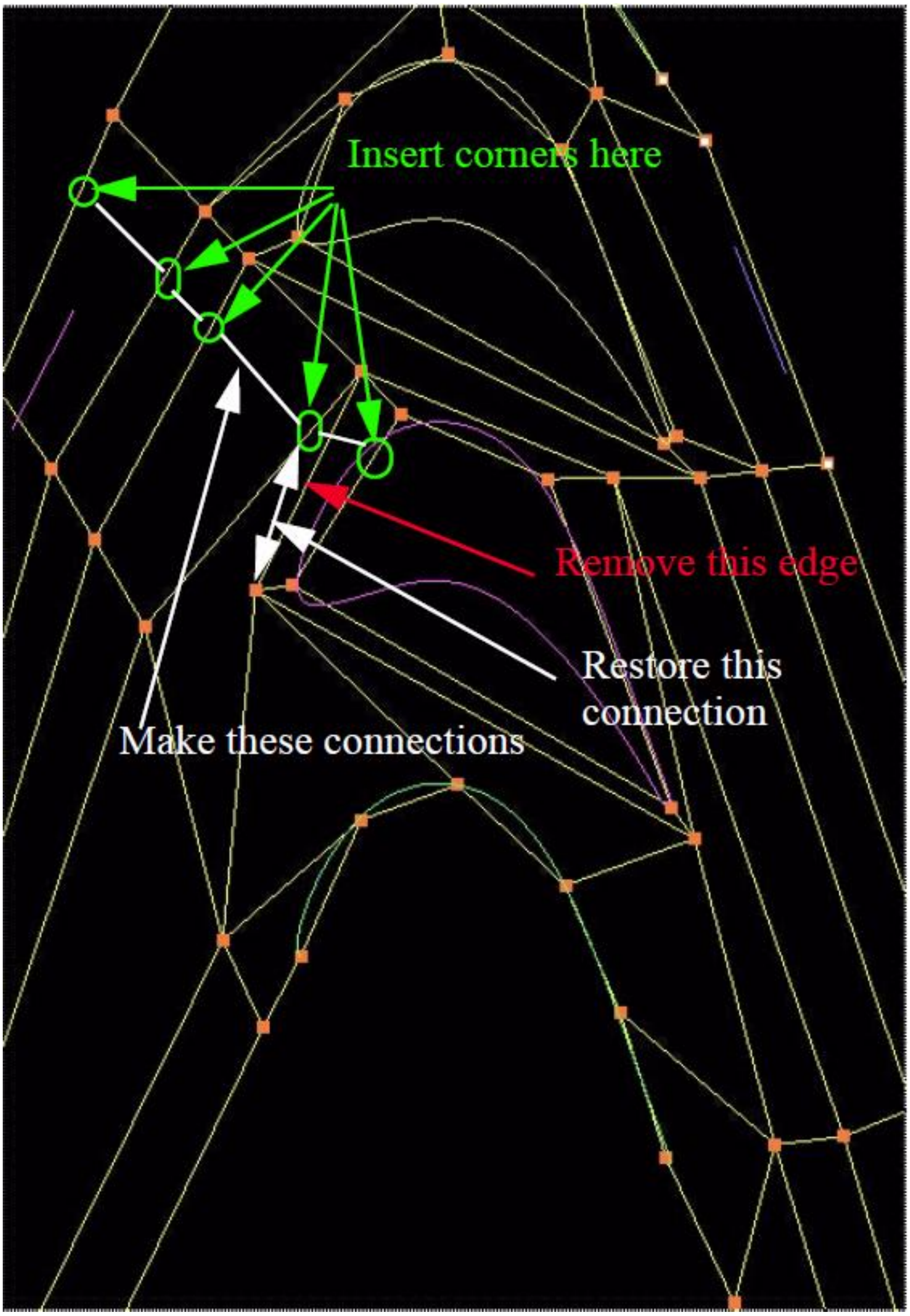
The edges marked in the above figure are the intersection of these adjacent blocks. We have to concentrate on these edges to solve out problem.

The solution of this problem requires that the direction of flow of the grid lines changes more gradually. This can acheived by a changing the topology near these edges.

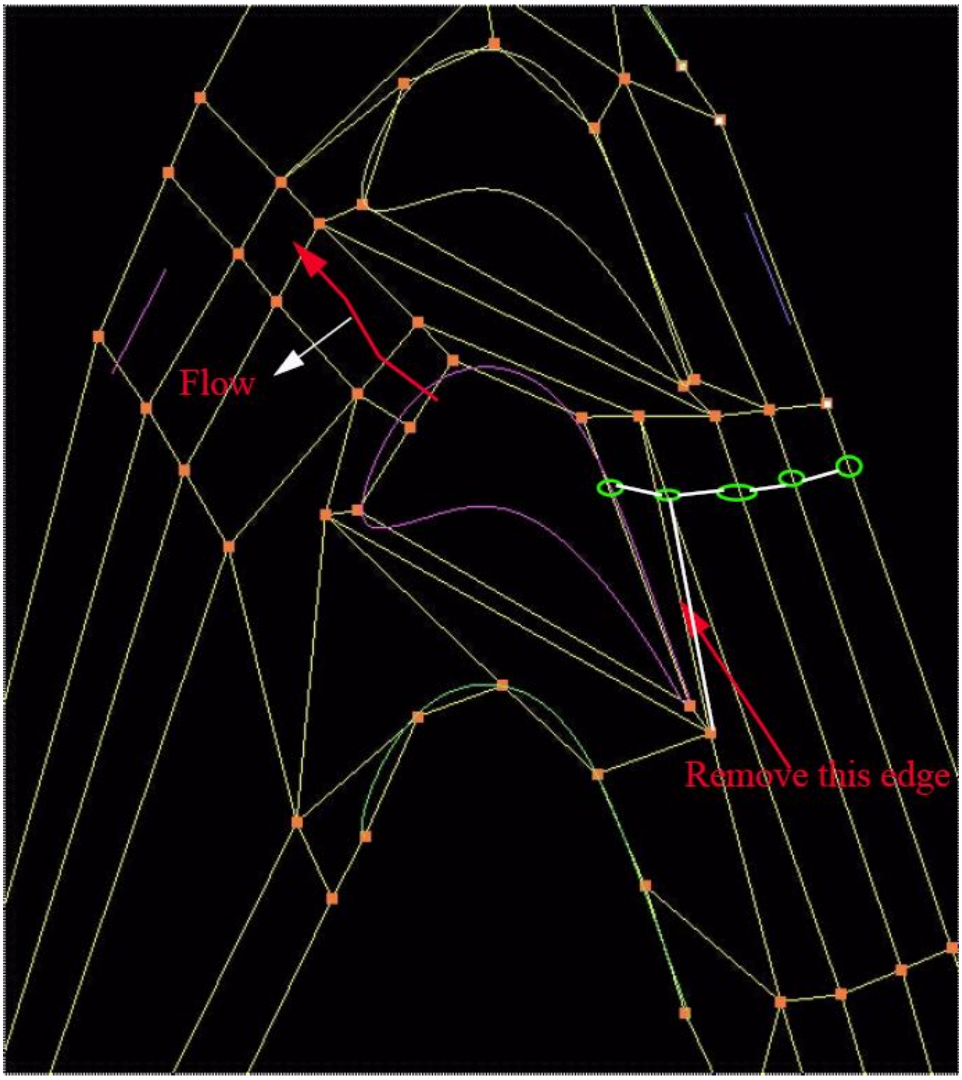


In the above figure, points have been moved around to help you visualize things better. Notice how the topology dividers, a set of edges, act to seperate out the flow regions. If we can split this set of edges, and make the flow in the middle region go towards the side, it will make the flow lines change more gradually.

This can be achieved in a way similar to the one in which you have split the 6-point singularity. Just slide a copy of that particluar edge down. For the left side, this can be achieved by removing the edge shown in the figure below, insering edges at the locations shown. Finally restore the broken connection.

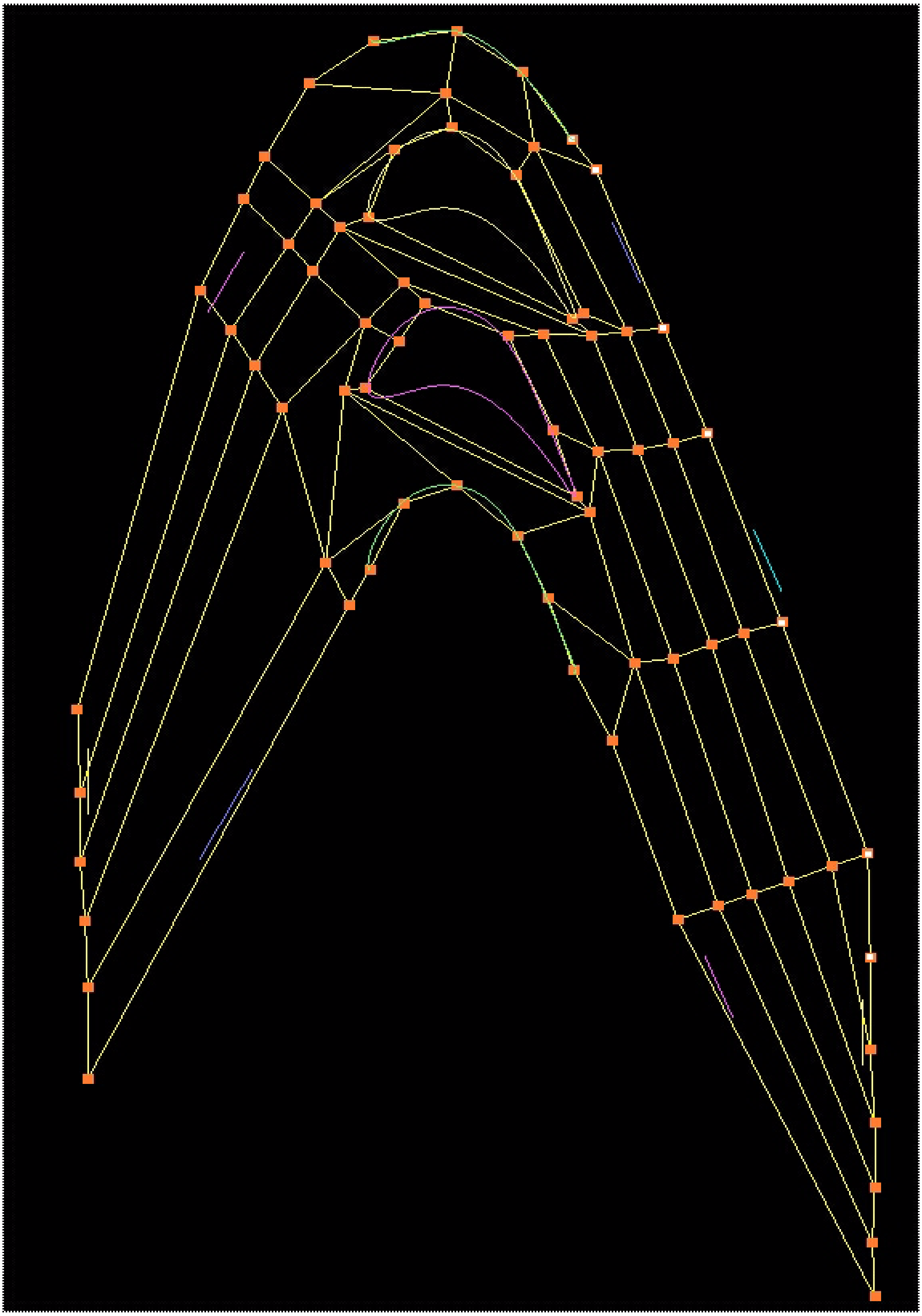


Remember to use the **insert mode** appropriately when you insert the corners. After you have done the splitting, your topology should look like this.

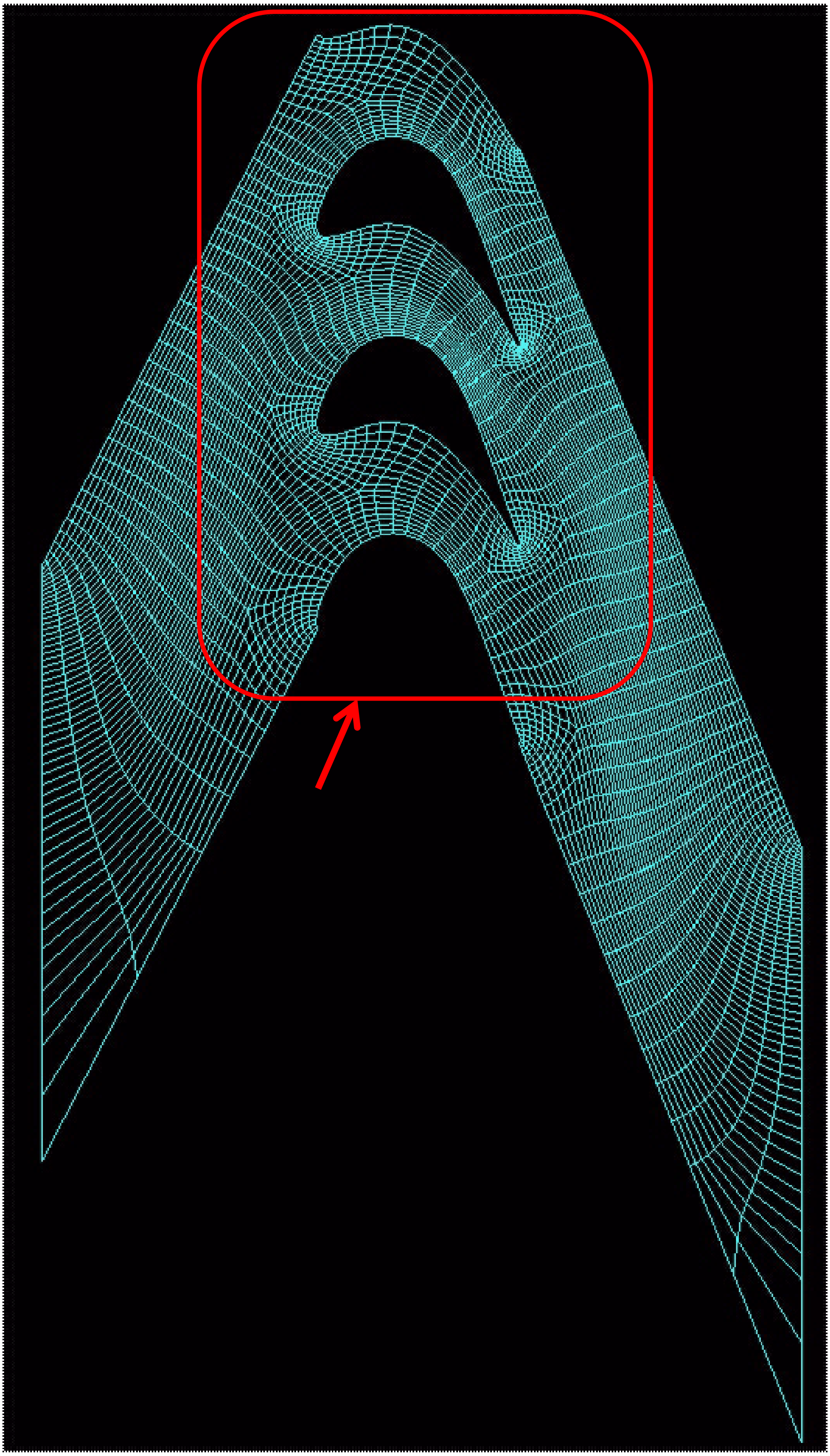


Doing a similar set of operations as shown above, you can avoid the strecthing in the right side topology too. Notice the intermediate blocks generated have a flow towards the side, hence providing for an intermediate flow to make the change of flow direction more gradual.

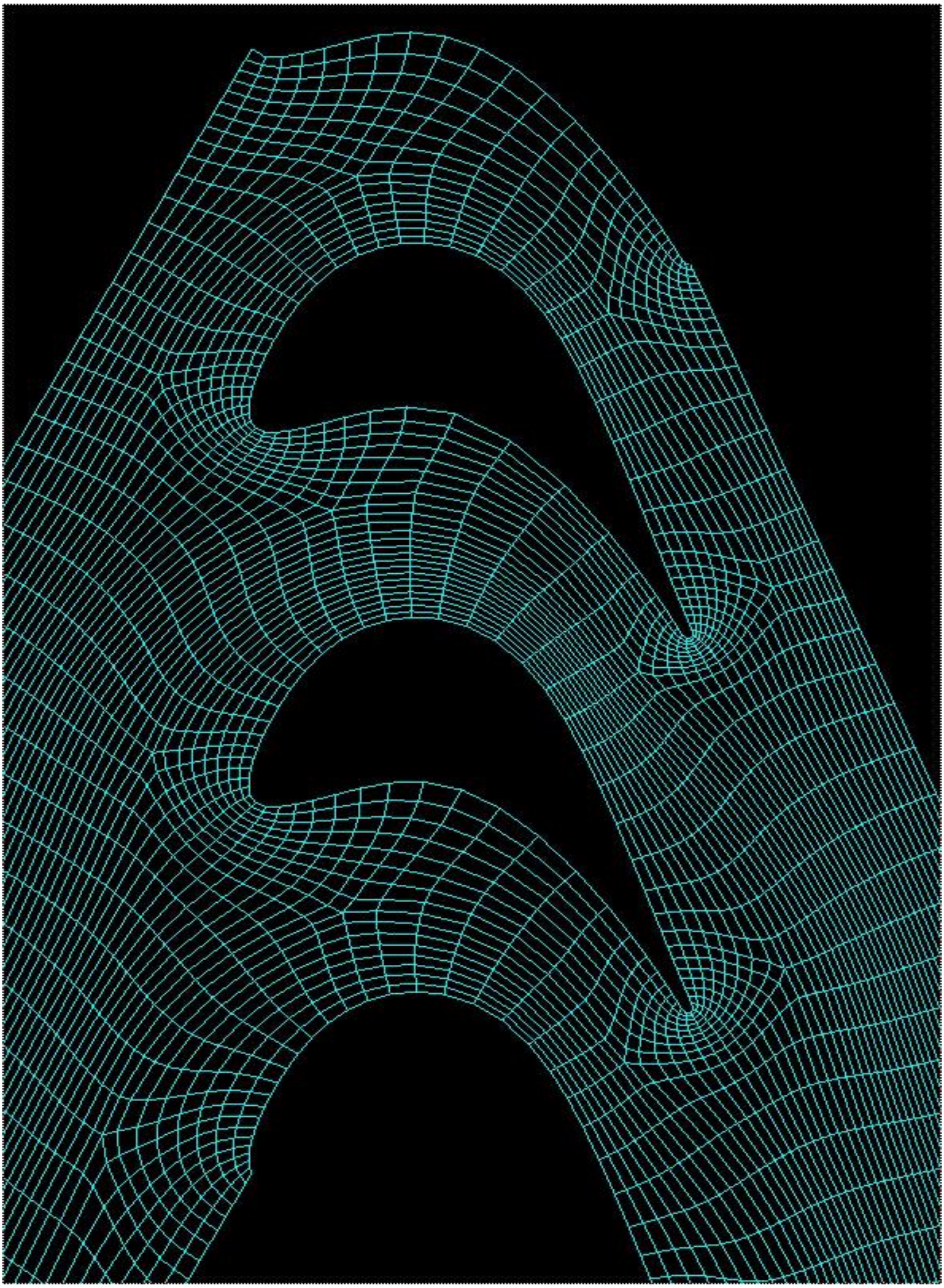
The final topology looks like the one shown in the picture below.



The grid generated from this topology will look like this.



Note the improvement in the quality of the grid.

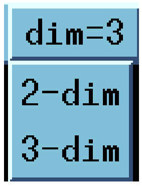


Note the improvement in the quality of the grid.

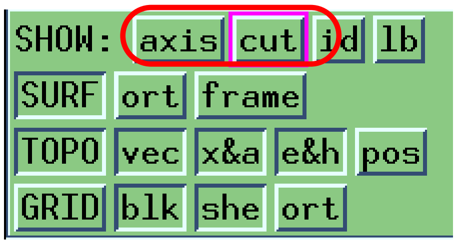
Step 6 Making the case three dimensional

Now, for the fun of it, we are going to make the case three dimensional. Making this case three dimensional is pretty simple. The first step is to go to the **dim** pull down menu and select **dim=3**. The next step is to create two planes parallel to the plane to bound the test section in the z direction. And then, simple copy the present topology with op back edges to the cut plane to get the complete three dimensional case.

First step



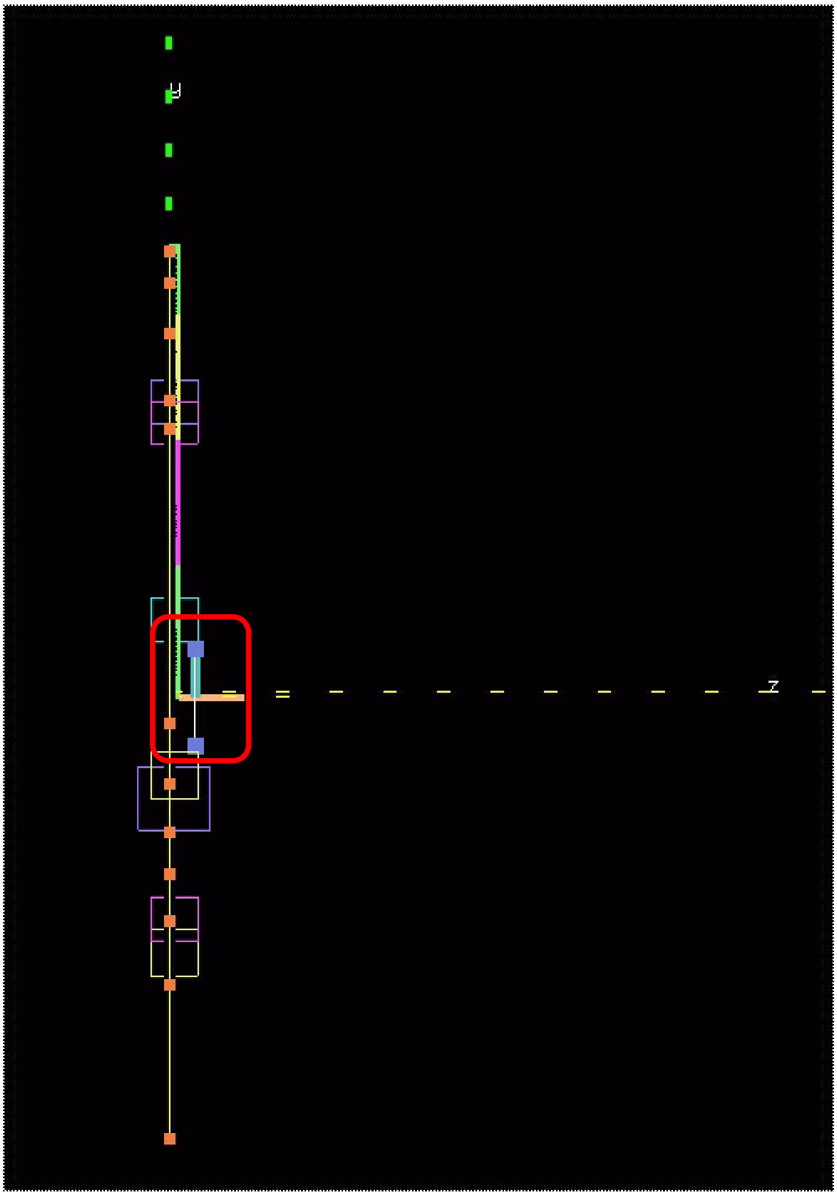
Now turn on the **axis** and **cutp** in the SHOW panel.



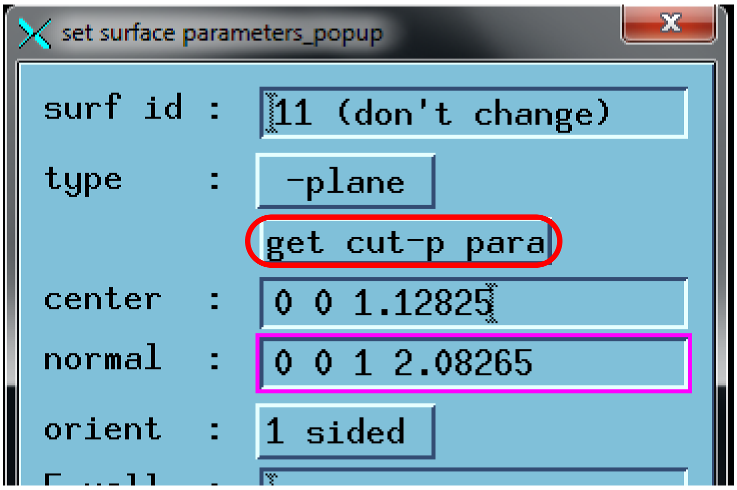
After this, rotate the geometry and snap it to the y-z plane. Turn on the **hand** in the CUTP panel. Drag the cutp toward the right as shown in the figure below.

You are now ready to create a plane. The plane you are going to create is going to at the position of the cut plane, and parallel to it. Go to the **surf** menu and select **load -plane**. You will get a **set parameter window**, in which there is a **get cutp para** button. Pressing this button will automatically enter the cut plane position and its normal into the appropraite places in the window.

Now, drag the cut plane to the other end in the same way and create a plane there. Take care that you do not drag the cut plane too much to the left or right, for this will create planes too far from the geometry.



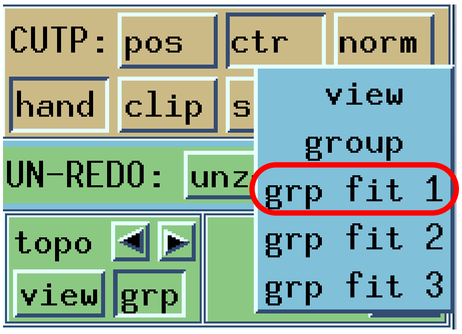
Drag the cut-plane towards the right



Use the get cutp option

After you have created the planes, you have to create the topology.

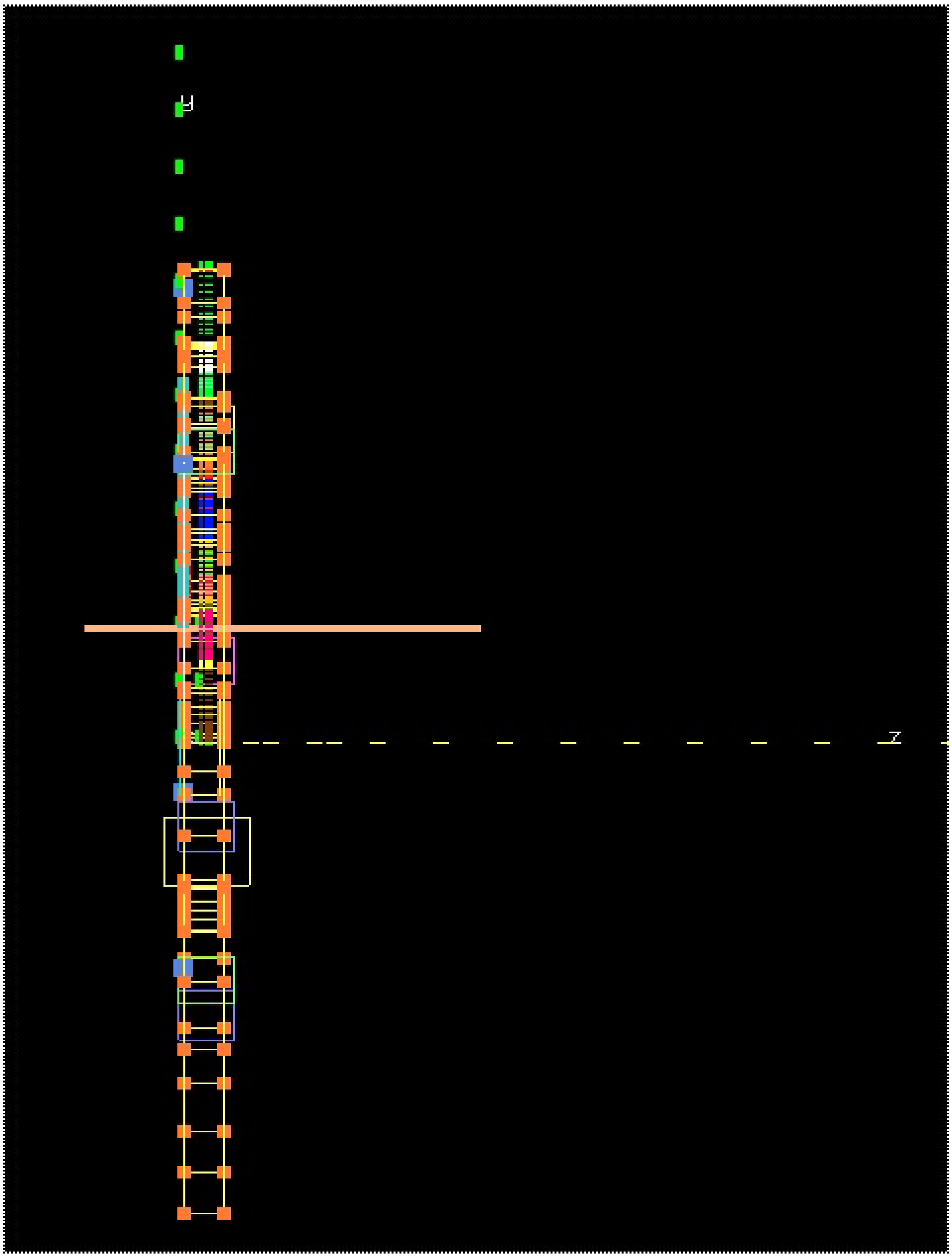
Put all the points of the present two dimensional topology into group 1. Now, select the **ctr** button in the CUTP panel to get a pull down menu as shown below. Select the **grp fit 1** option.



You will the cut plane position itself to the center of the group. Now, drag the cut plane out to the right and place it at the location of the plane. Use the **cp with drop back edges** in the TOPO panel to copy the topology to the right. You can now remove the left part of the topology. Now drag the cut plane to the left plane and use **cp with drop back edges** again. This will give you a three dimensional topology. Assign the left set of edges to the left plane and the right set of eges to the right plane. Generate the gird around to look at the three dimensional grid. You will see that its not very different from the two dimensional one.

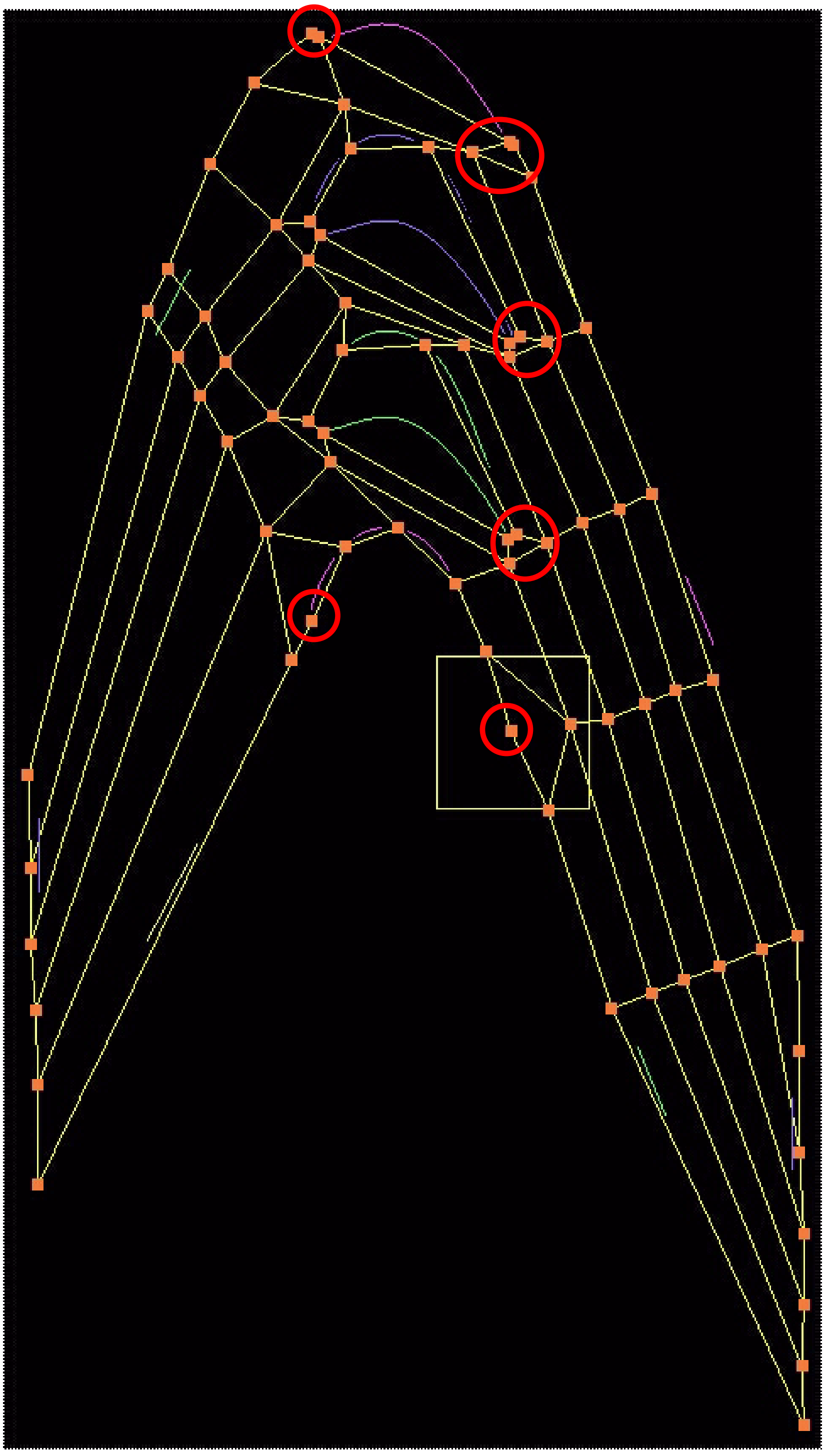
Step 7 Compact enrichment

You are now ready to add internal surfaces to enhance the grid at important points. Remember that the geometry is now a three dimensional one.



The three dimensional topology

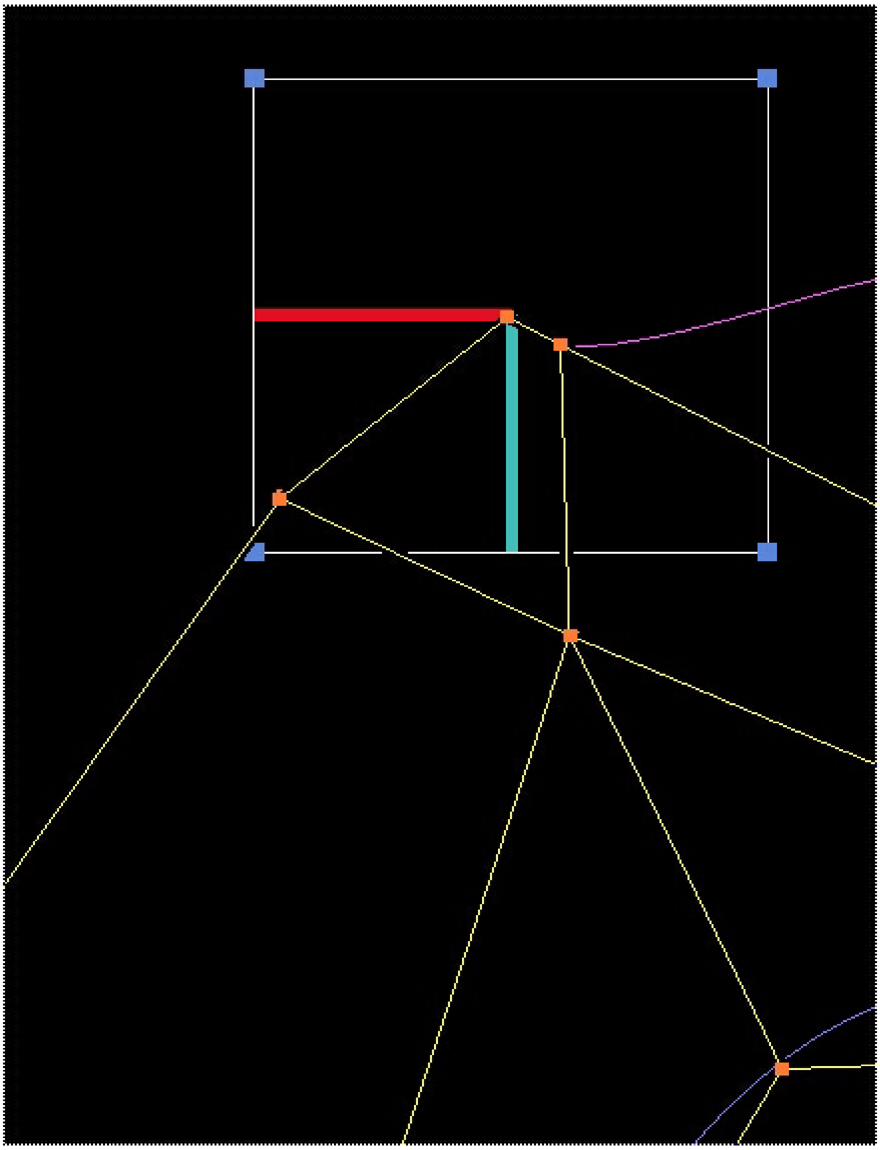
Let’s first mark the points where we need to enrich the grid by adding internal surfaces. These are marked in the picture shown below. They are the corners and the trailing edges of the blades.



Let’s add compact enrichment at the top left corner of the geometry first.

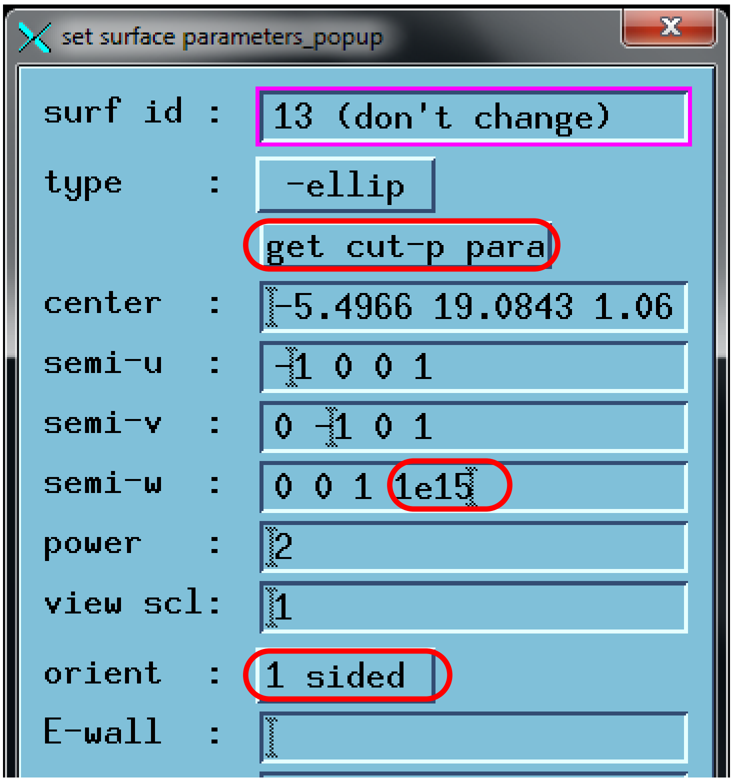
To do so, add the internal surface first. The obvious choice is a cylinder. The **get cutp para** can again be used to create this surface.

Make the normal to the cut plane parallel to the z axis and place the cut plane such that the center of the cut plane is positioned near the surface intersection as shown below. Also, size the cut plane to make its size 1. This is so that we can have a cylinder of radius 1 as the internal surface.

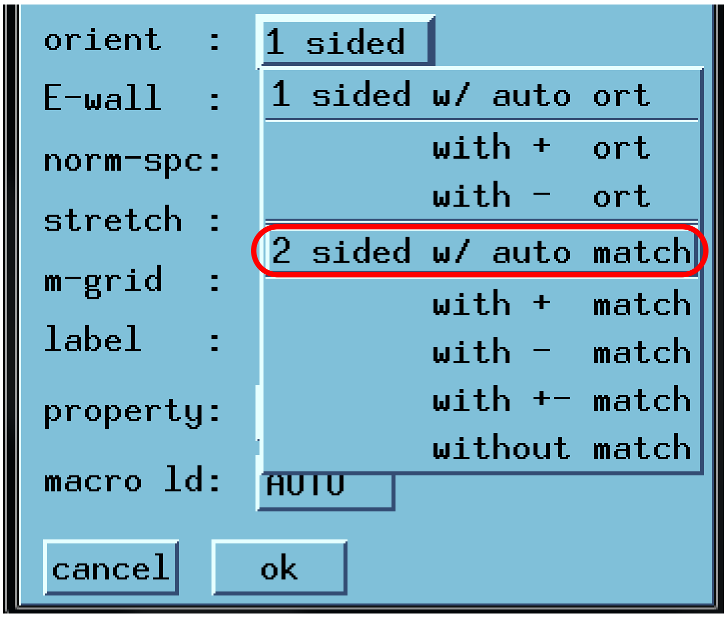


Position the cut plane as shown

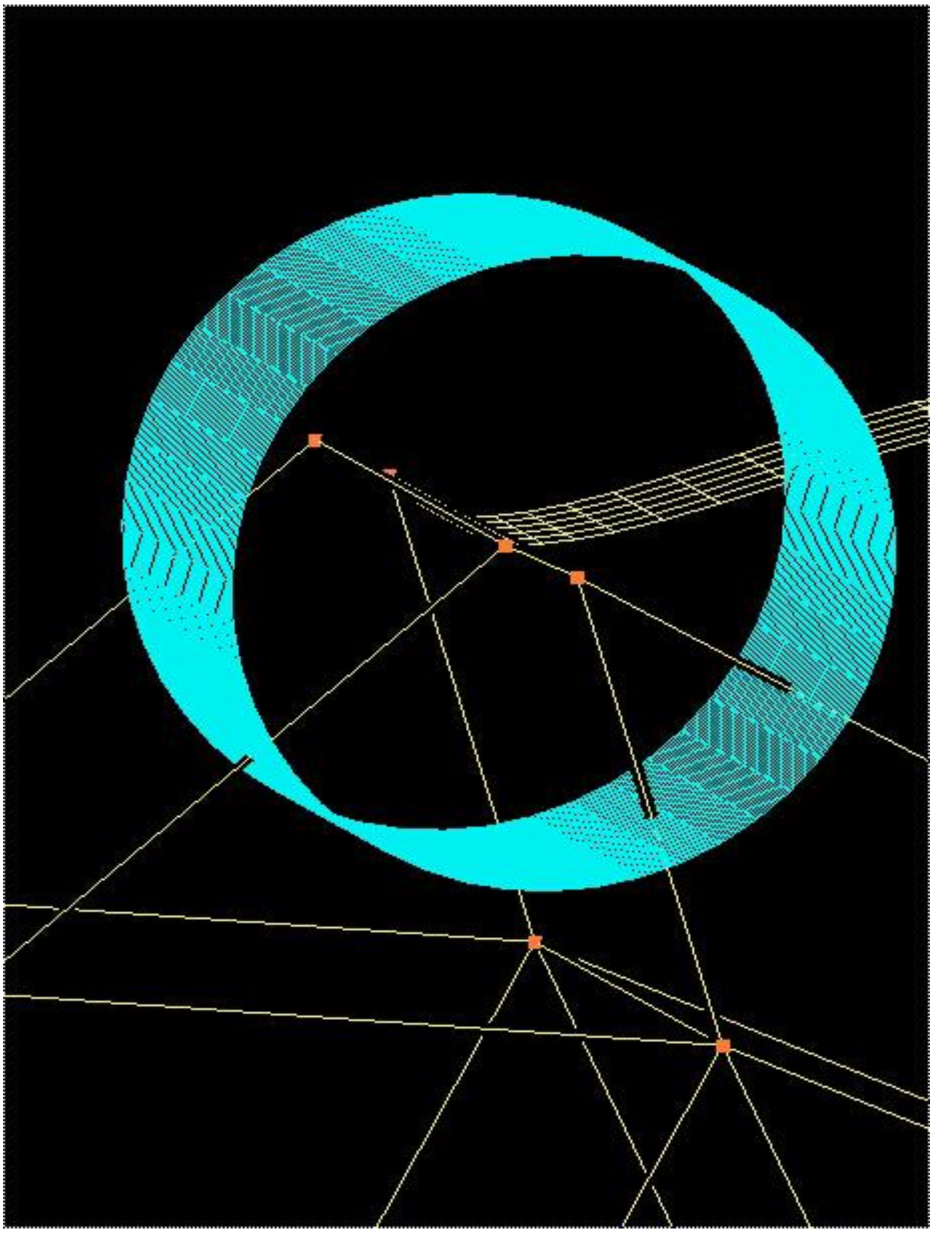
Go to the **surf** menu and select **load -ellip**. Press the **get cutp para** button to load the position parameters. Since you have to load a cylinder, give the **semi-w** parameter a very large value as shown.



The orientation of internal surfaces are 2 sided, for both the sides are going to have grids growing out of them. Change the orientation to **2 sided with auto match**.



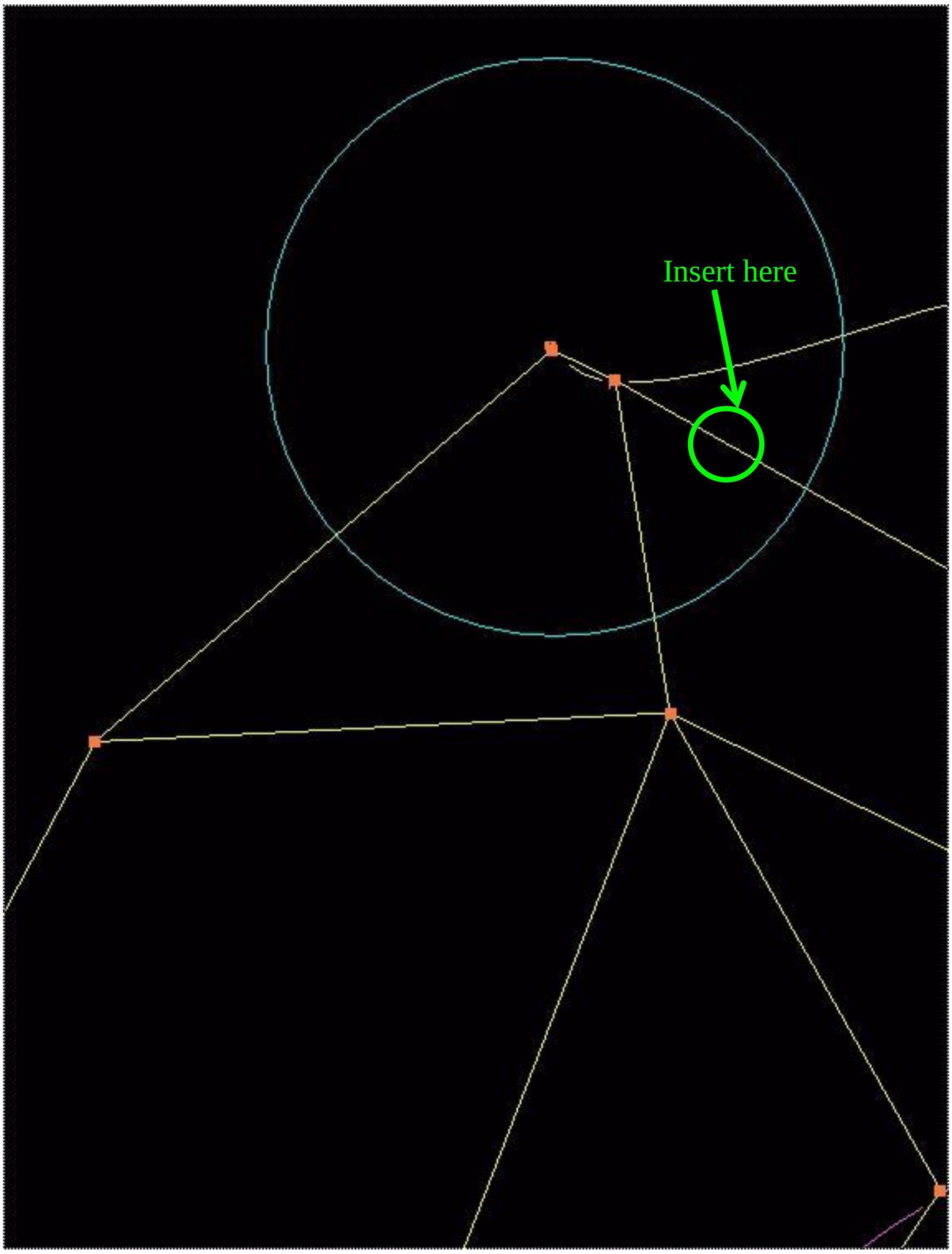
Press **ok** to create the surface. A three dmensional view of the surface is given in the next page.



We will be working mostly in two dimension. But keep in mind that the topology is three dimensional.

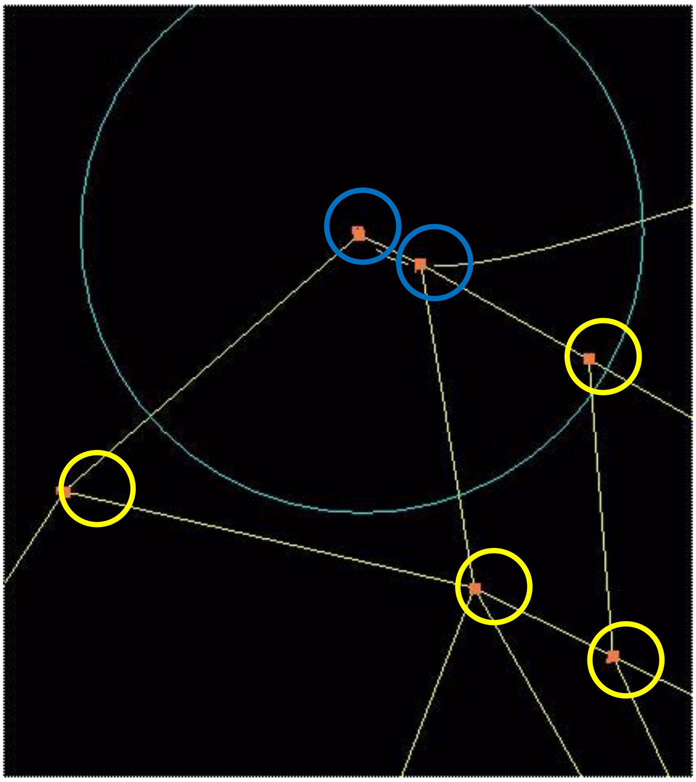
Now, we have to create a topology around the internal surface. A good topology around it should be such that the surface is wrapped both from the inside and the outside. A fast way to do this is to use the techinique of wrapping with respect to refernce.

First create an insert at the location shown in the next figure. It should create a topology which we can work with.

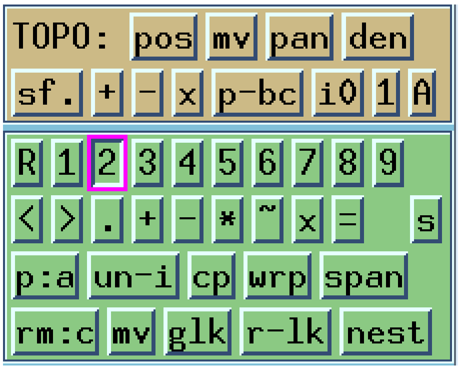


Use the all insert mode **i:a** to do this insert. You will get two more corners as shown in the figure below.

Now add the points indicated by the yellow and the blue circles to group 1, and add the points indicated by the yellow circles alone to group 2. Turn on the group 2 with reference to group 1 by having group 2 as the current group and setting the background group mode button to **R**.

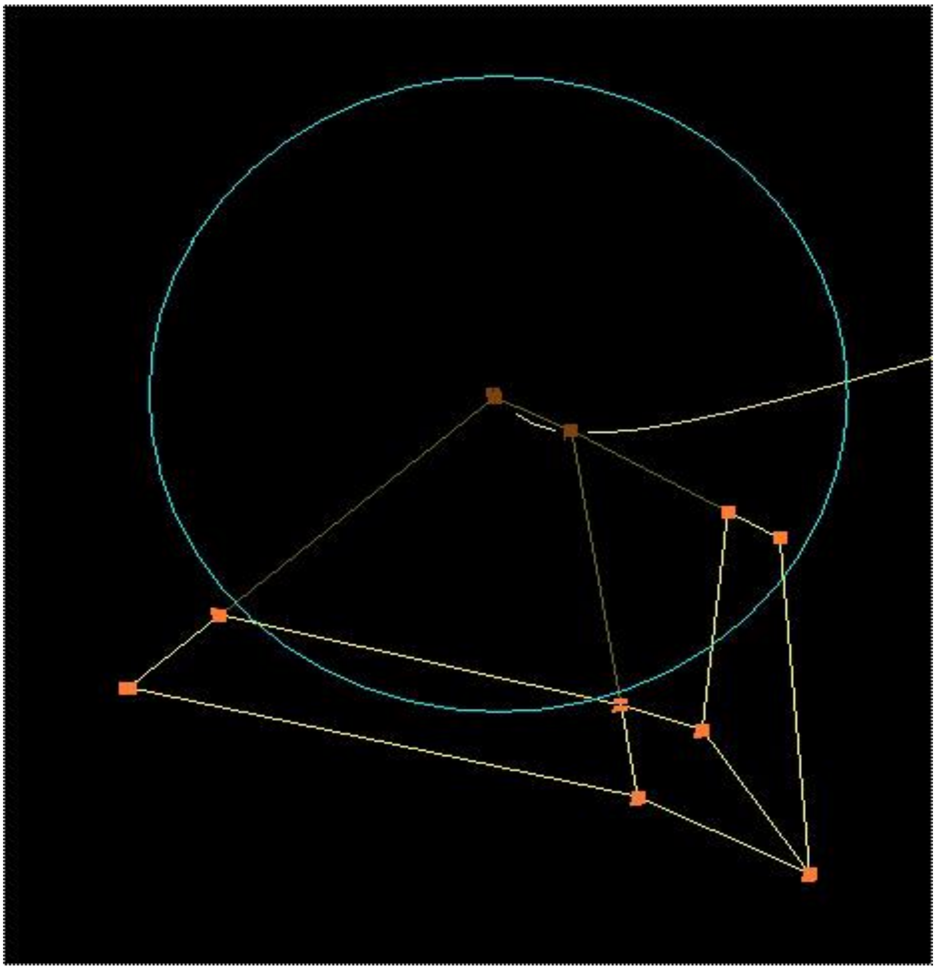


Yellow and blue to group 1. Yellow to group 2.



Background group mode

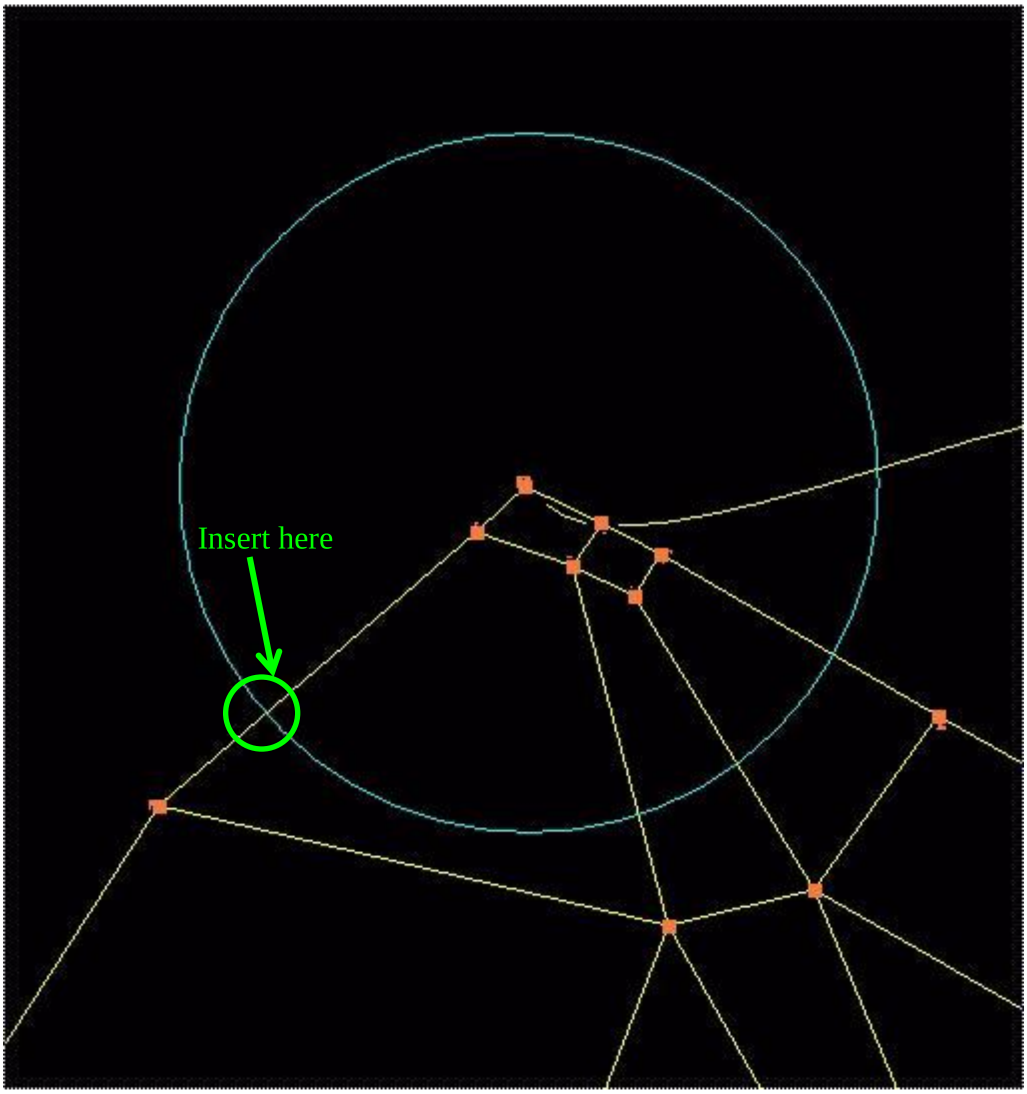
After this, wrap the group by 25% smaller. You should be able to get a topology as show in the figure below.



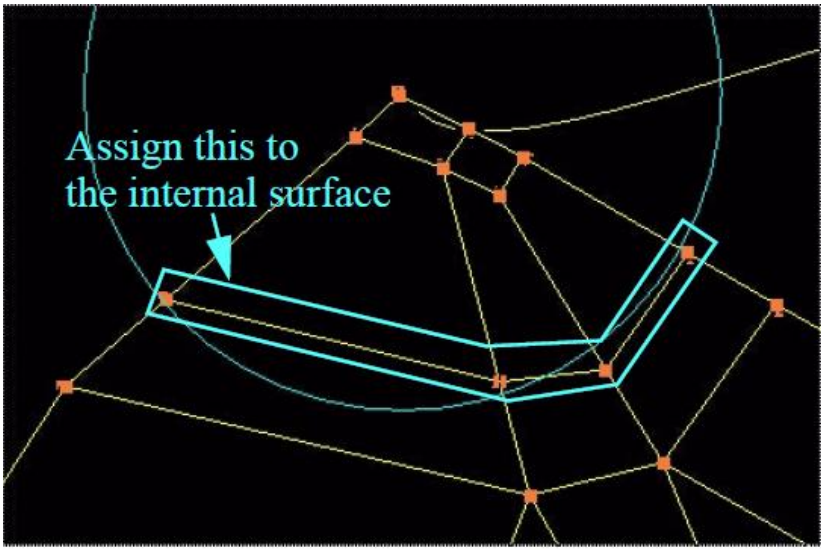
The wrap and the group

Now, you will have move around the points to make the topology look like the one shown in the figure. Remember that the internal surface should have a wrap both on the outside and the inside.

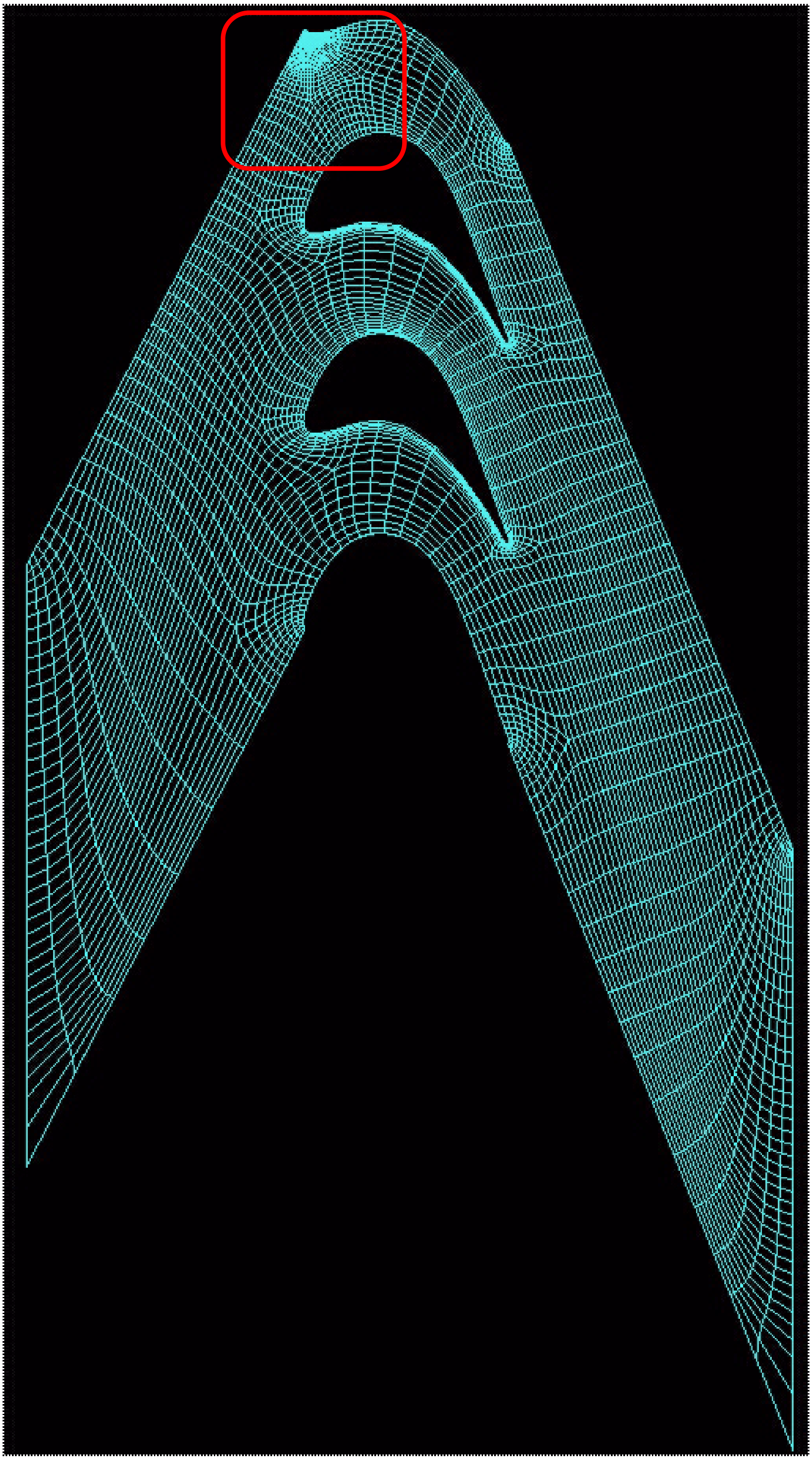
So, make an insert (with the insert mode set to **i:a**) at the location shown. This will create the required topology. The newly inserted corners has to be assigned to the internal surface. After you do that assignment, you are ready to run Ggrid on this topology.



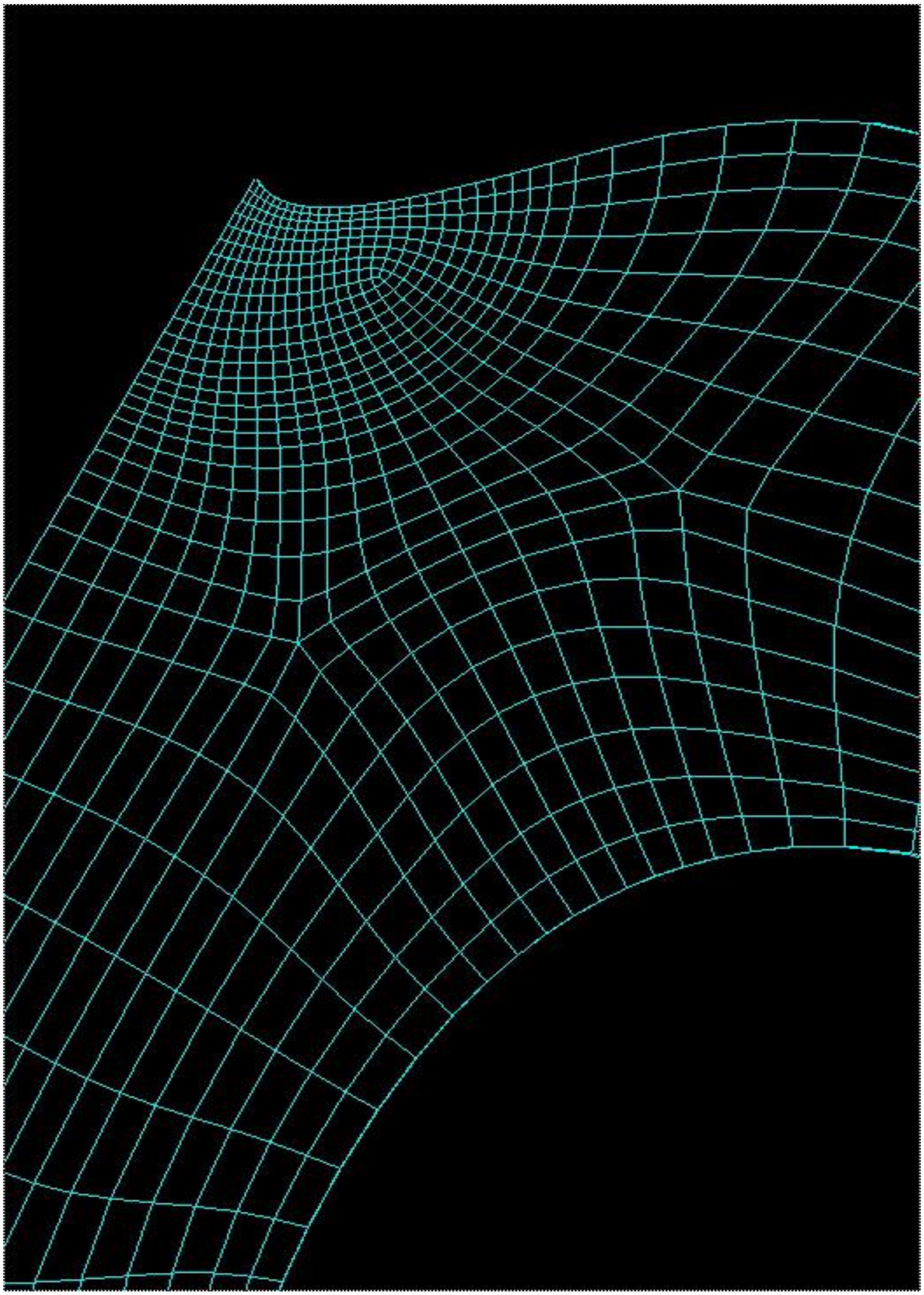
The same topology with corners moved



After the insertion

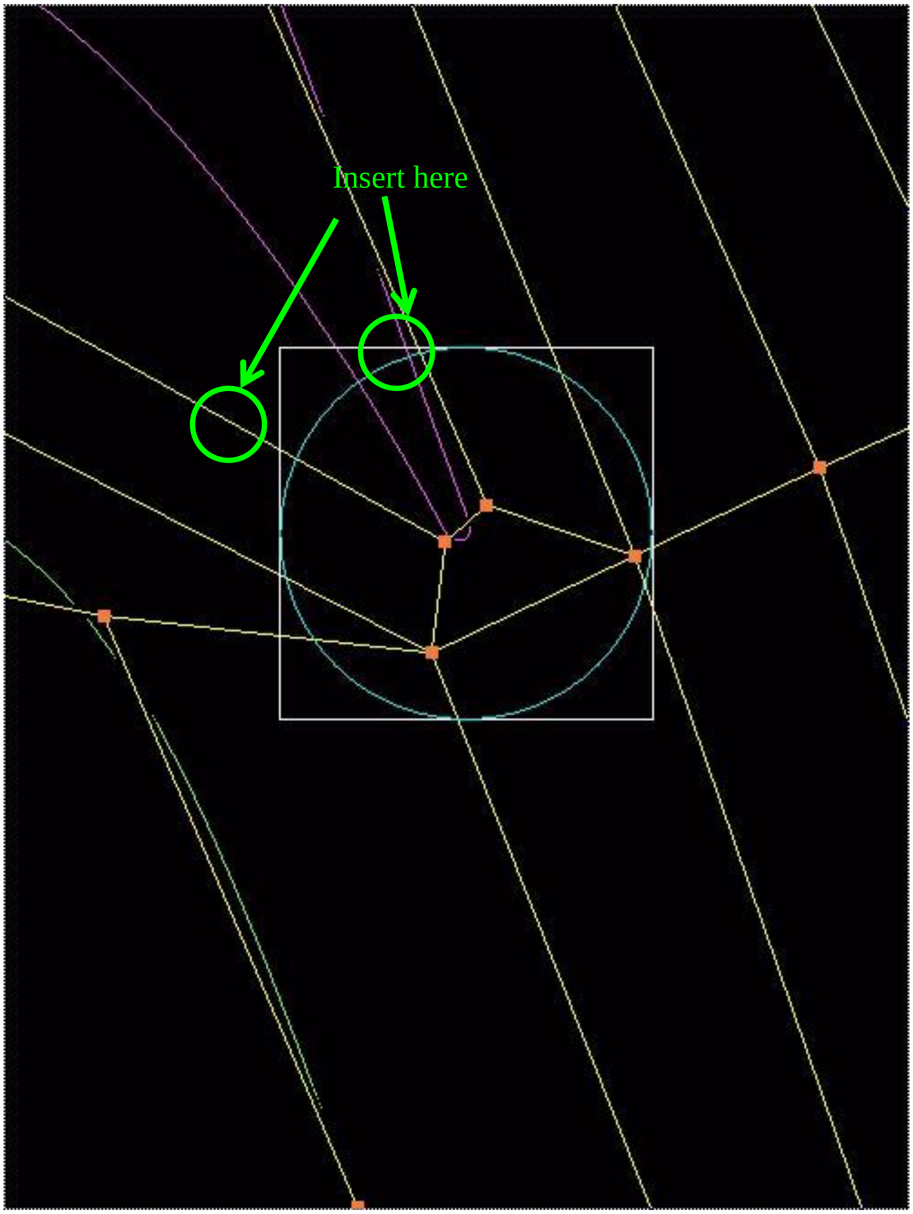


The Grid



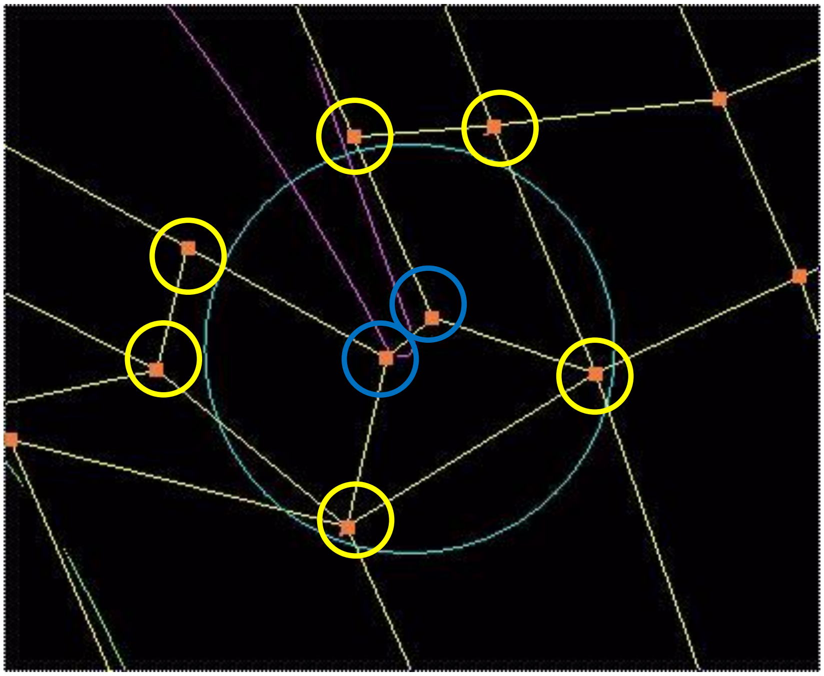
The compact enrichment

Now, lets add compact enrichment to the lower turbine blade. Create a cylinder near the tip of the trailing edge of the turbine as shown below.

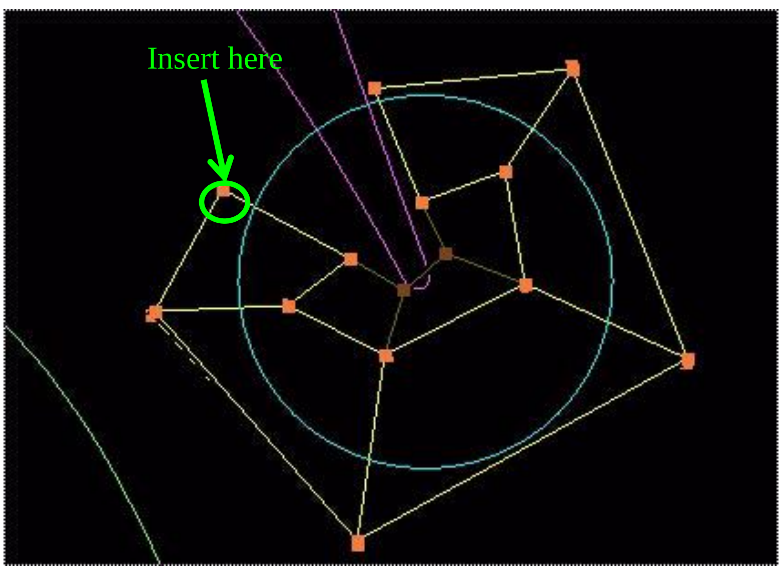


After this, insert corners (with the all insert mode on) at the locations indicated above.

In picture below, add the corners marked by yellow and blue to group 1, and add the yellows alone to group 2. Then, wrap group 2 by making it with reference to group 1.



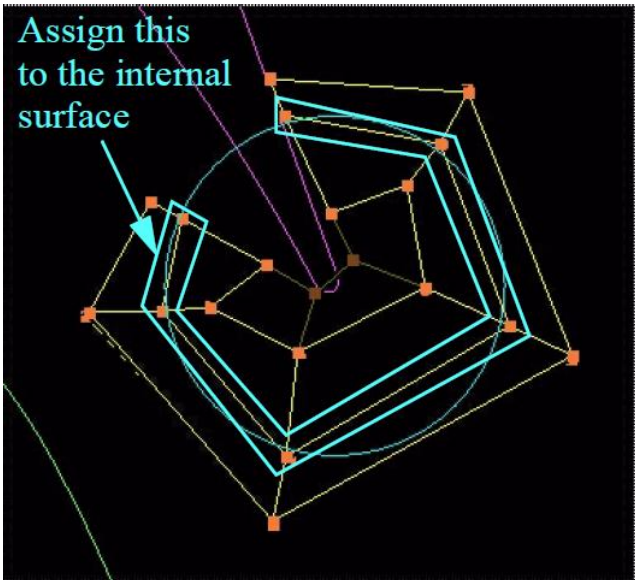
Yellows+blues to group 1. Yellows to group 2



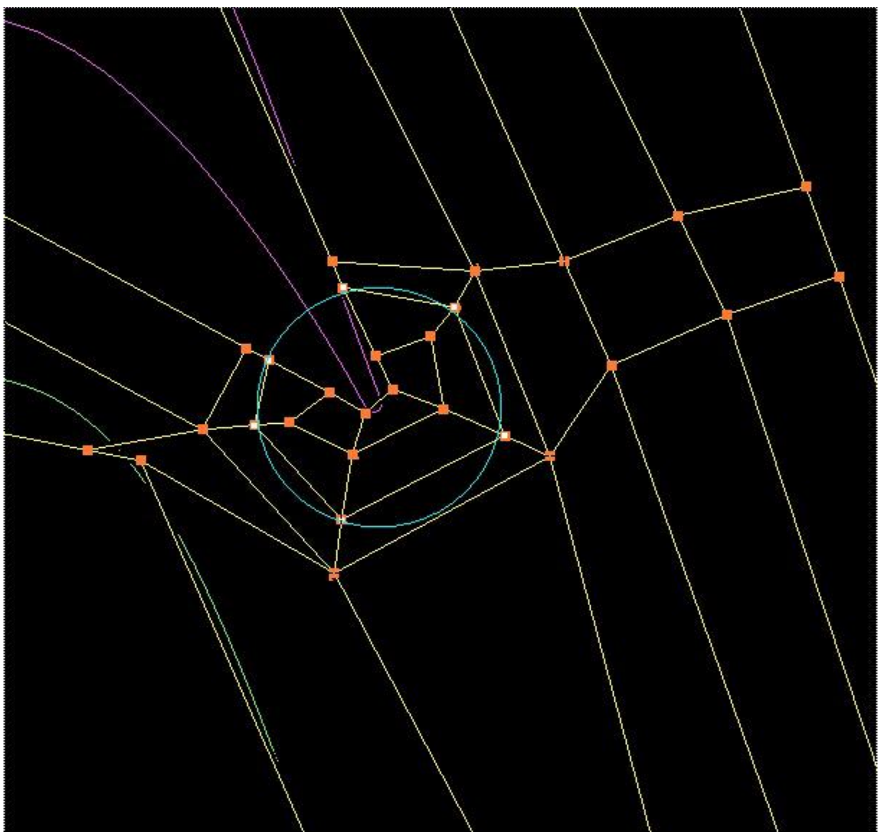
After wrapping

Insert at the location shown to get the topology shown below. Assign the inserted corners to the internal surface.

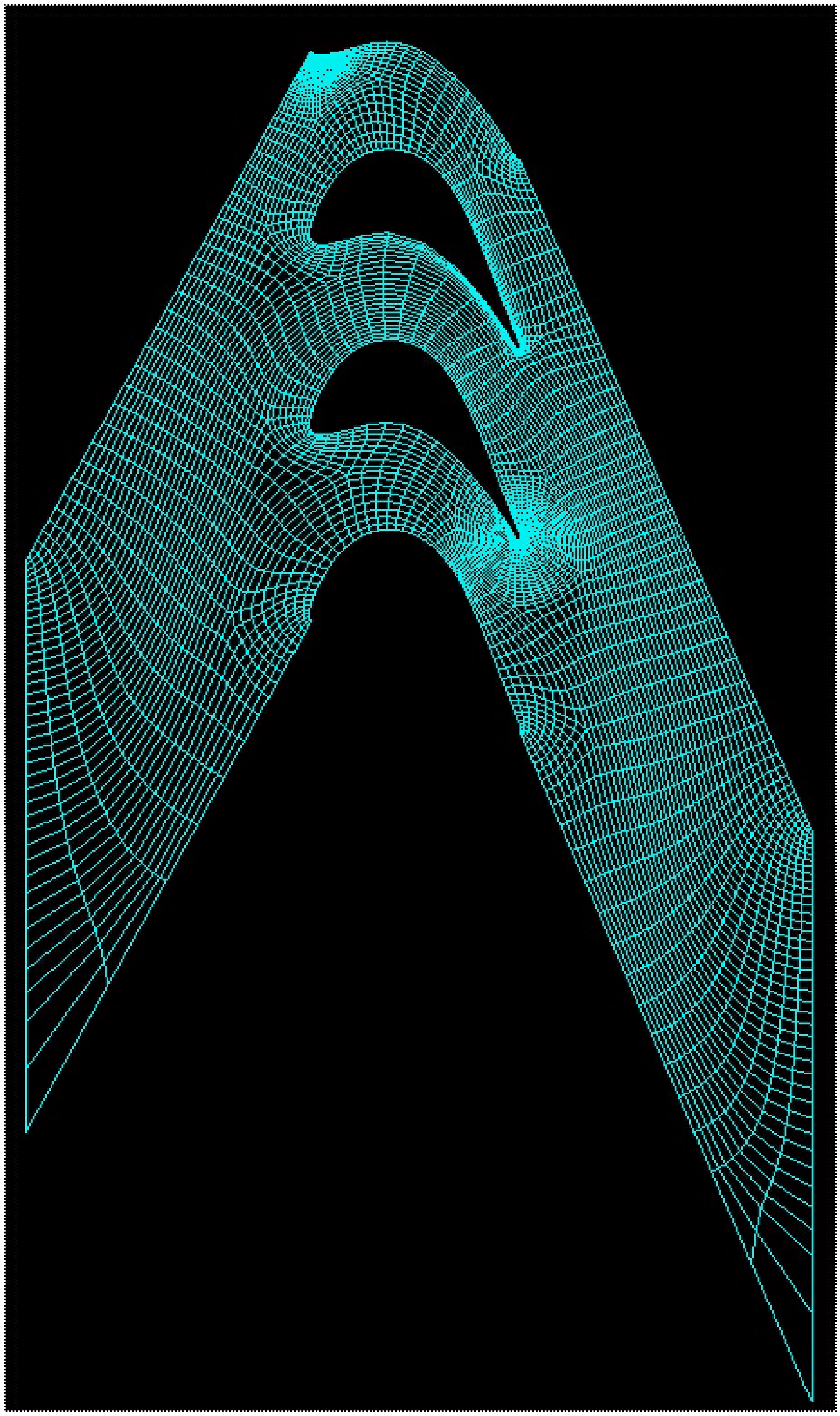
After this, you can start the Ggrid process and look at the grid.



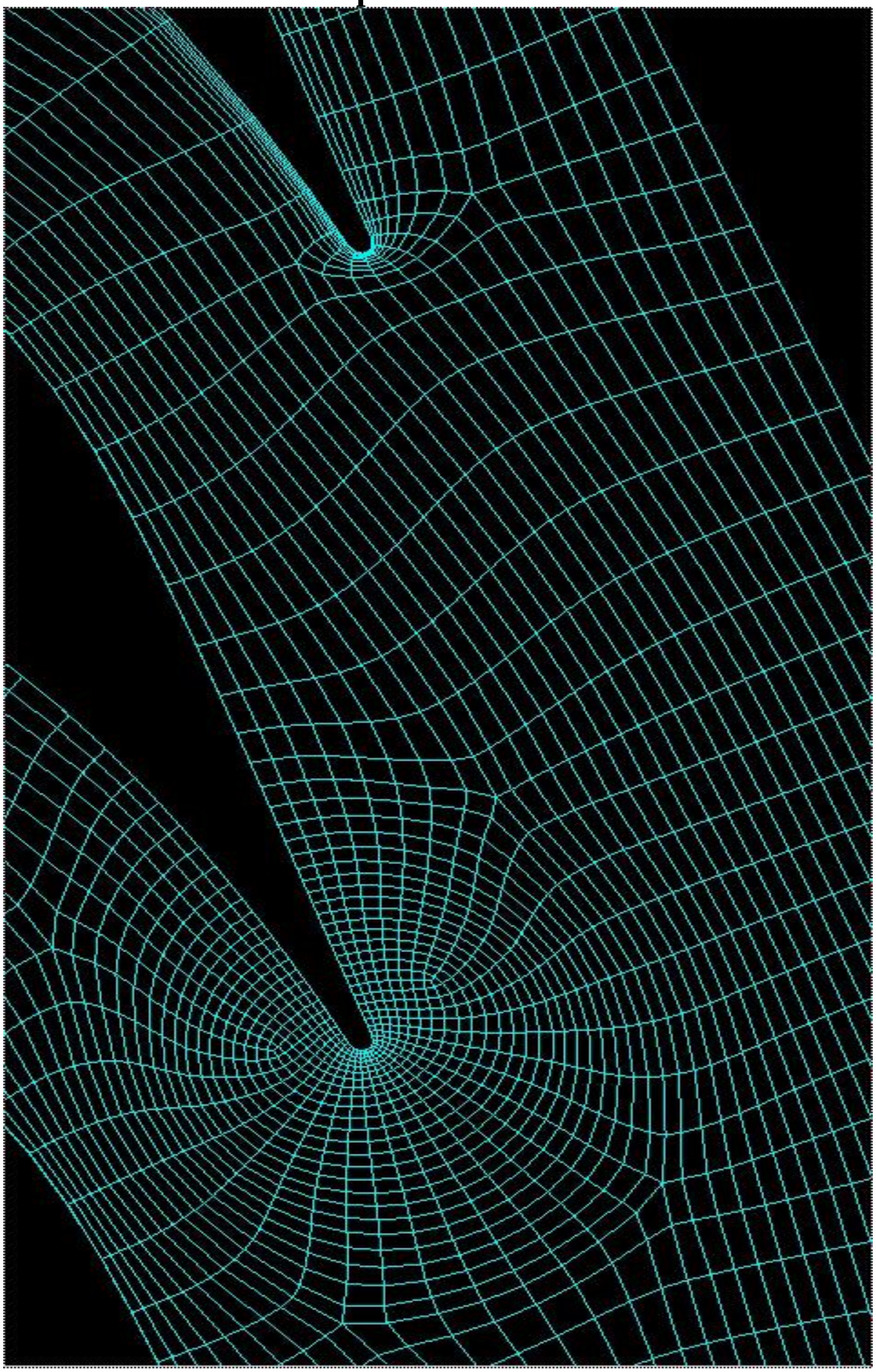
The topology near the trailing edge



The Grid

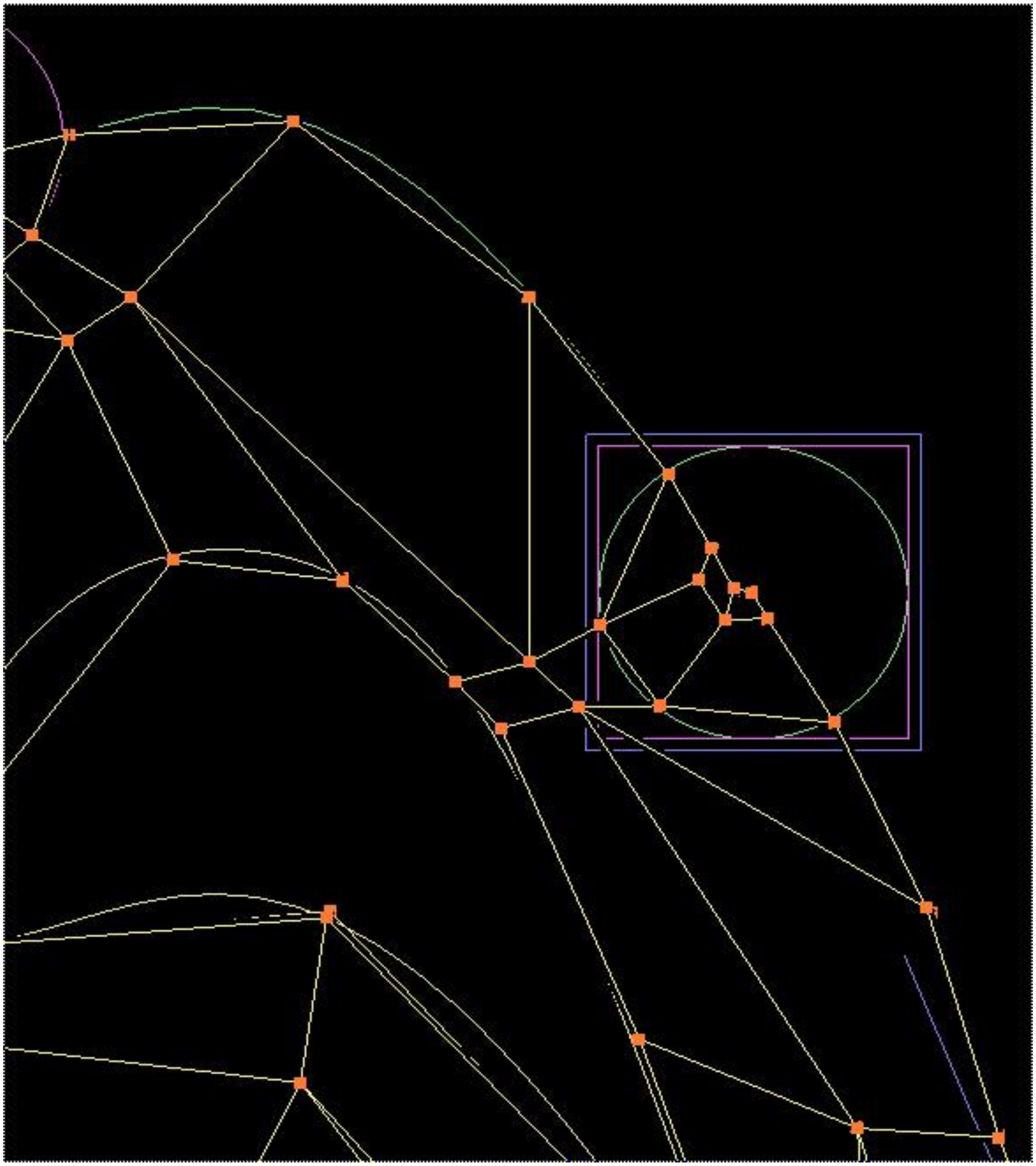


The Compact enrichment



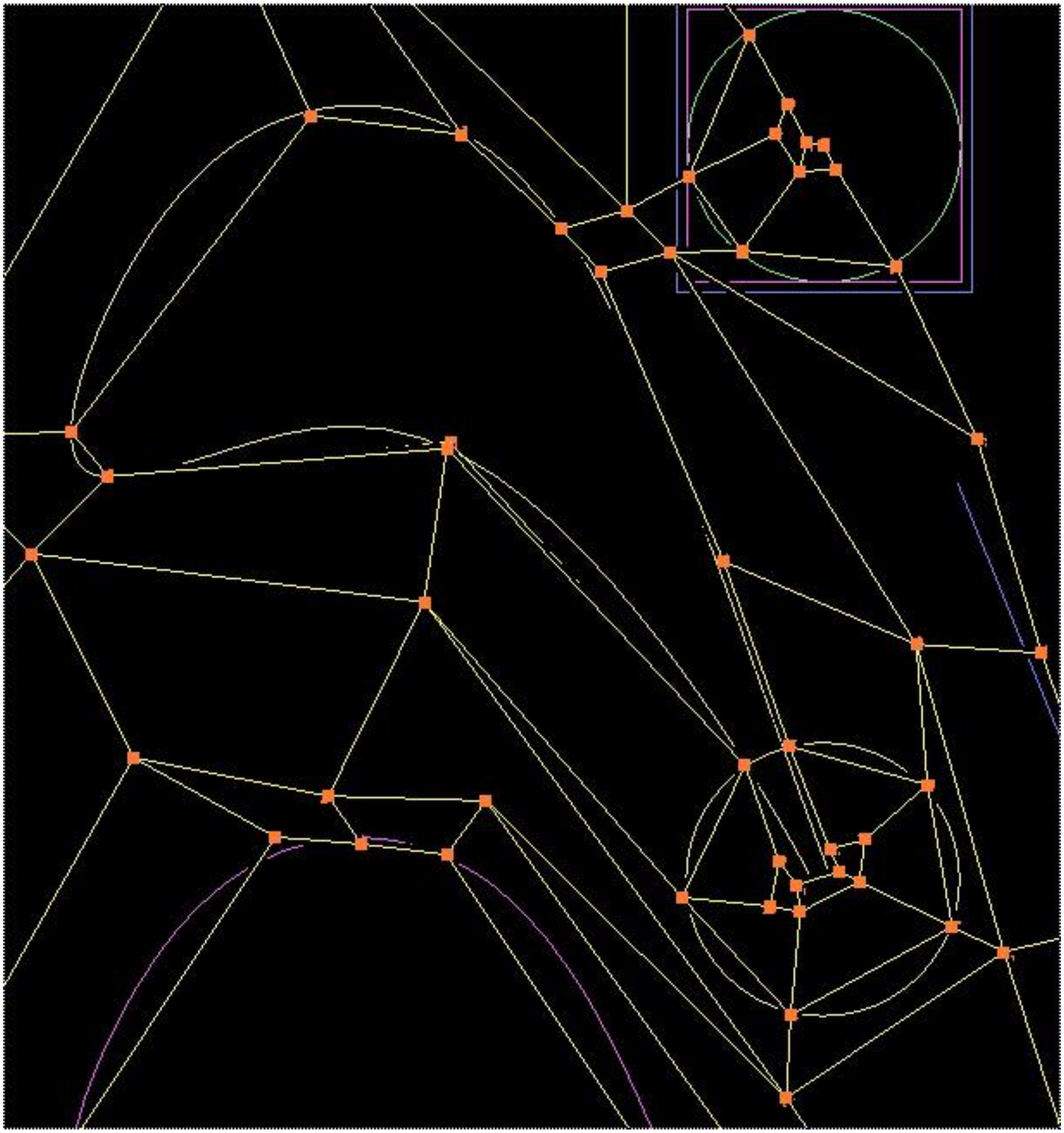
Note the difference between the trailing edges of the upper and lower blades

Similarly, you can add compact enrichment to the top right corners, the upper blade trailing edge and the lower corners.



Top right corner

Trailing edge of the upper blade



The lower two corners