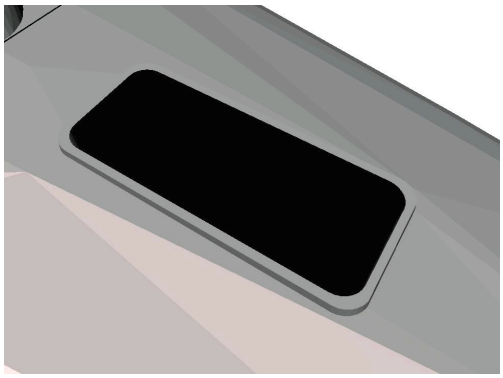
A guide to making a 3D model watertight using ReMesh.

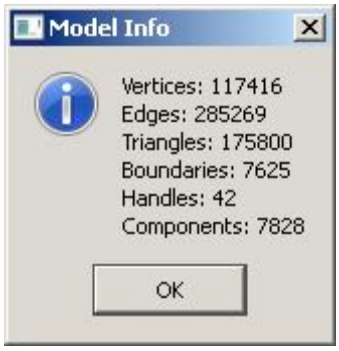
Models from the Internet and other repositories are often made for renderings in movies and pictures. For this purpose they are far from watertight. If you are creating models yourself with *watertightness* as a goal, try constructing the models from a basic shape. From there you can extend the shape and keep the model as one *shell*. In both cases this tutorials serves as a guide to post-edit a model to make it watertight.

1. Preparing and analyzing the model

Keep an eye on these statistics, as they will indicate your progress to a watertight model.



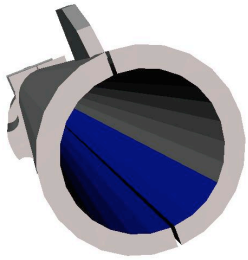
- First, make sure the model is **normalized** in the origin (*Edit → Normalize Mesh*)
- Some of the areas on your newly opened shape may **appear black**. These parts are often separate shells. The surface of the mesh is oriented towards the inside of the shape and need to be flipped outside. To do this, use the *flip shell*-tool. (*Edit → Flip Normals*)
- Check the current state of the model by viewing the following properties (*File → Properties*):
  - **Components**: The most important property is components. This indicates how many separate *shells* (small shapes) are contained in the opened model. Most methods will only work when the complete shape is merged into one single component.
  - **Boundaries**: If a model is not completely closed, it contains boundaries. When there is a hole in the shape, the number of total boundaries can be reduced by filling up the hole. And so there are multiple ways to reduce the number of holes. Ideally the final shape has zero boundaries. Some programs/methods will not allow boundaries or otherwise generate errors. It is therefore important to remove all boundaries of a shape.



    - **Tip**: to get an idea where the boundaries are, use the *Select boundary*-option. (*Selection → Select Boundary*)
  - **Handles**: Handles are loops in the shape. Although some models have handles as features (imagine a standard teapot for example), it often happens that during the process of reducing components and eliminating boundaries small bridges are created in the mesh. These are not intended features. You should try to reduce the number of handles as much as possible and be alarmed if there are a lot.

2. Pre-Remesh phase

Before completely remeshing the model, a few steps need to be taken. The remeshing algorithm that will be used is Marching Cubes. To make results better for after the Marching Cube algorithm, a number of preparations need to be made. These preparations will greatly reduce the post-remesh work.



- First internal shells and triangles need to be removed. A typical example is the inside of a barrel of a gun. If this shape does not need to be maintained, it will save a lot of work if you remove them now. To do so select the triangles and delete them.

- After deletion glue boundaries of two opposite sides of the barrel. This gluing can be done using the *Join boundary*-tool. (*Interaction → Join Boundaries*)
    - **Tip**: Sometimes just joining boundaries with the default settings might give an ugly effect or does not work at all. In these cases it is best to first join some single boundaries using the *just connect*-option. After that you can manually fill the remaining holes using the fill holes-tool from the interaction menu. (*Interaction → Fill holes*) Not to be confused with the (*Algorithms → Fill holes…*)-tool, since this tool tries to fill all holes in the entire model.
- At this point there are probably still holes and multiple shells, so do not worry when you see no progress yet.

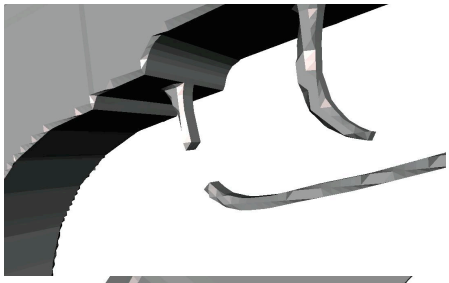
3. Marching Cubes

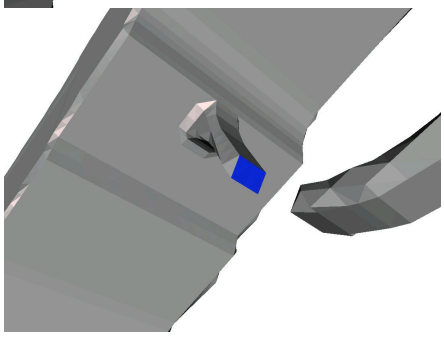
Marching cubes will attempt to completely put the shape in a 3d grid and create new triangles for each cell. Based on the coordinates of the current mesh entering/leaving the cell.

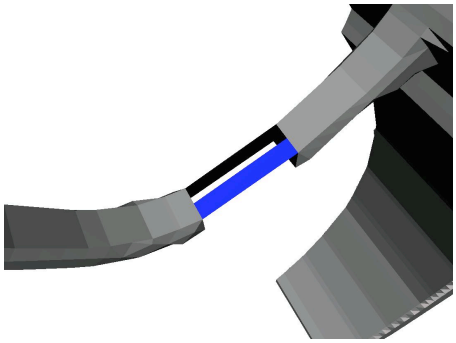
- First, select the tool from the menu. (*Algorithms → Remesh → Marching Cubes…*)
- Now a value for the precision needs to be chosen. Generally a value of 250 or 300 performs best. A higher precision will leave smaller details intact. However, a precision too high will also detect the gaps and mistakes you are trying to fix (and besides create enormous amounts of polygons).
    - **Tip**: Try experimenting with these values to see there effect, you have one *undo*-action (*Edit → Undo*) to switch back to the state before the algorithm.

- The result will never be perfect, so make sure you have all the details and as less 'pulverised' mesh as possible. Removing the internal mesh and shells has already prevented part of the pulverisation.

4. Reducing Components







You are now ready to start working on the quality of your model. The first task will be to merge all existing shells into one.

- To get an idea of which parts of your model are currently separated from the main shape, use the *remove smallest shells*-tool. (*Check and Repair → Remove Smallest Shells*)
- When too much shapes are disappearing, which is usually the case, try gluing the parts together using the *join boundaries*-tool explained earlier.
    - **Tip**: Sometimes there are no boundaries to join the separate shapes with. In this case you can select and delete some to create nicer boundaries. Right clicking and dragging a selection sphere often proves useful in this case. You can also use the join boundaries tool to bridge larger distances.
      Tip: This might sometimes result into ugly triangles. Selecting and deleting a larger area after and using the fill holes-tool to retriangulate can fix this.
- At one point after fixing some of the separate shells, all the important pieces of your model will remain when using the *Remove smallest shells*-tool. When this is the case save the changes.
  You have successfully made the object into one single shell!

5. Removing boundaries and refining the model

The fastest way to close all boundaries is to use the *algorithm fill holes*-tool. (*Algorithms → Fill holes…*) This will not always lead to the best results, as a lot of attached polygons are not well connected.

- Instead, first use the *select boundaries*-tool again.
- Check whether the selected polygons will change the shape a lot when deleted. If not, press delete to remove the polygons.
- Some shapes will require the gluing using the *join boundaries*-tool to make them into one shell again, or simply because it will otherwise change the structure.
- Use the *fill holes*-tool to close the boundaries.

    - **Tip:** In the mean while also using the *remove smallest shells*-tool is important to remove small leftovers of the editing actions and to see whether all the important parts of the shape are still connected.
    - **Tip:** Some of the fill hole actions might not result in a smooth enough surfaces. You can use the resulting selection together with the *Laplacian smooth*-tool (*Algorithms → Laplacian smooth…*) to smooth the surface.
- Then, when the properties-information window says there are no boundaries and only one component you are more or less done.

- Too give the set a more coherent look you can also *Laplacian smooth* the complete surface one or two iteration. Bear in mind that smoothing will create many polygons.
    - **Tip:** To really tune the model use the *check geometry*-tool (*Check and Repair → Check Geometry*) for finding badly triangulated surface where algorithms might trip over.
- Finally make sure small protrusions and loops (*handles*) are taken care of. This is the easiest after smoothing the entire surface, as they appear clearer.