CAD to XR practical guide

This guide will demonstrate a conversion from a CAD model to a real time friendly 3D model. It is recommended to read the theoretical research paper before or with this guide to better understand the reasoning behind each step. The tutorial frequently refers to the relevant *chapters* of the paper in order to remain concise.

The conversion will be performed in a software solution called PiXYZ, version 2019.1.1.8. This software has been chosen because of its capability of doing the complete conversion in a straightforward manner. Most other solutions require in-depth knowledge and the use of multiple programs. However, after understanding this guide the principles should be translatable to other solutions as well. For more information about software alternatives, their strengths, weaknesses and capabilities, please refer to *chapter 4* in the theoretical paper.

Underlined `COURIER NEW` indicates user interface (UI) buttons that is pressed in order to perform operations. An arrow (`->`) shows in which order they are performed. A single operation may consist of multiple steps, which are indicated using bullet points.

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Overview

The complete workflow in PiXYZ consists of five stages. Each stage consists of one or more operations, which are subdivided in steps that are performed by the user. An overview of the five stages and their operations are shown in Figure 1. For each operation and its steps, screenshots are given that show how the step is performed in the software and how adjusting the parameters changes the outcome.

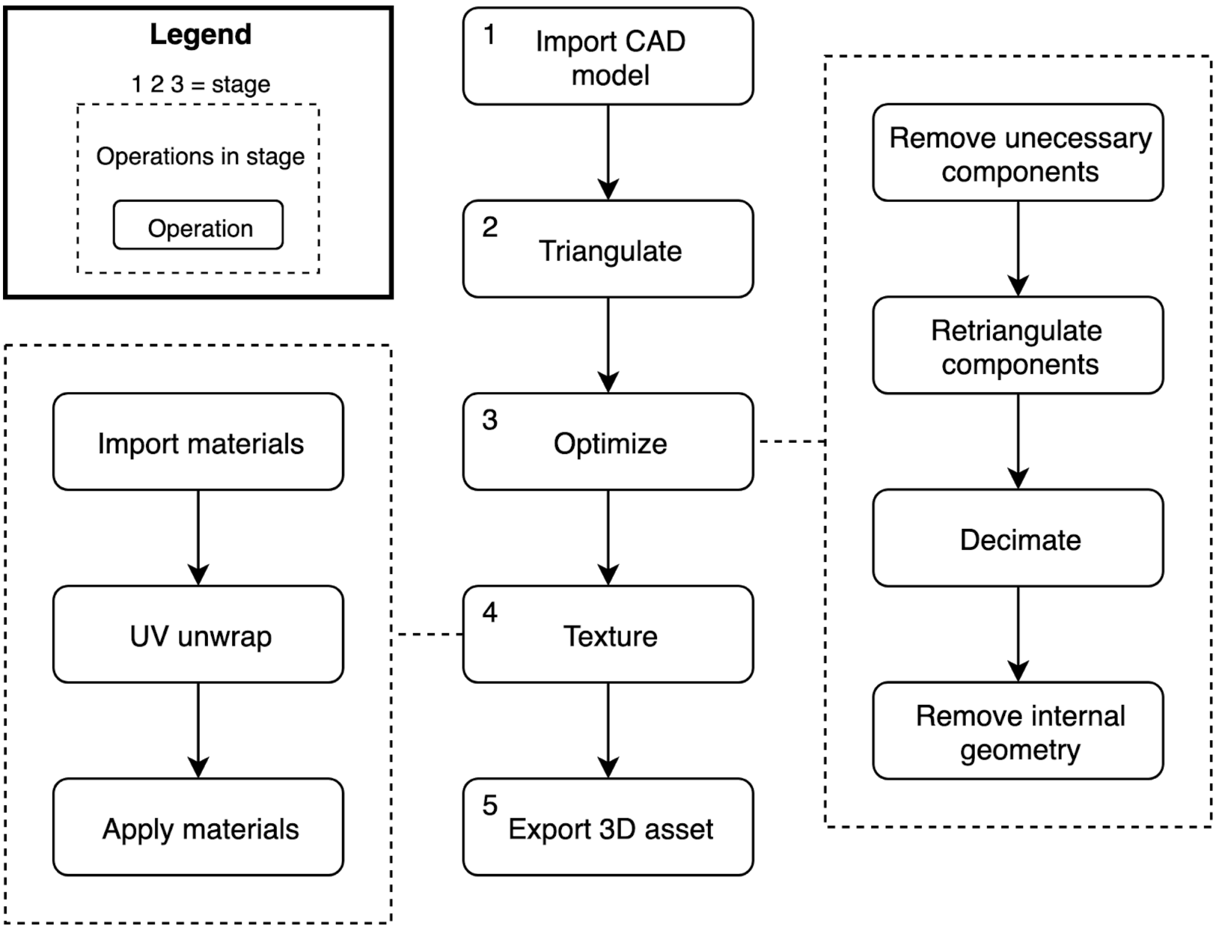


Figure 1. Conversion workflow in PiXYZ.

Workflow

Some of the operations in Figure 1 should be done multiple times with different parameters to find the right values for the specific use case. In PiXYZ, it is easy to undo and redo operations using `EDIT`->`UNDO` and `EDIT`->`REDO`. PiXYZ conveniently shows keyboard shortcuts next to some UI buttons. It is advised to learn them to improve one's efficiency.

0. Convert to STEP

This is the only step that is done outside of PiXYZ. It serves to transfer the CAD model from the original CAD software to PiXYZ. Although PiXYZ supports a wide variety of CAD file formats, it is still recommended to use the STEP file format whenever possible. For more information about STEP, refer to *chapter 3.1.1* of the theoretical paper. In Figure 2 an example is shown how this is done using FreeCAD.

- Select the CAD parts to be exported and navigate to `FILE`->`EXPORT` from the toolbar like in Figure 2.
- Select the `STEP` file format and press SAVE like in Figure 3.

Figure 2. FreeCAD File toolbar.

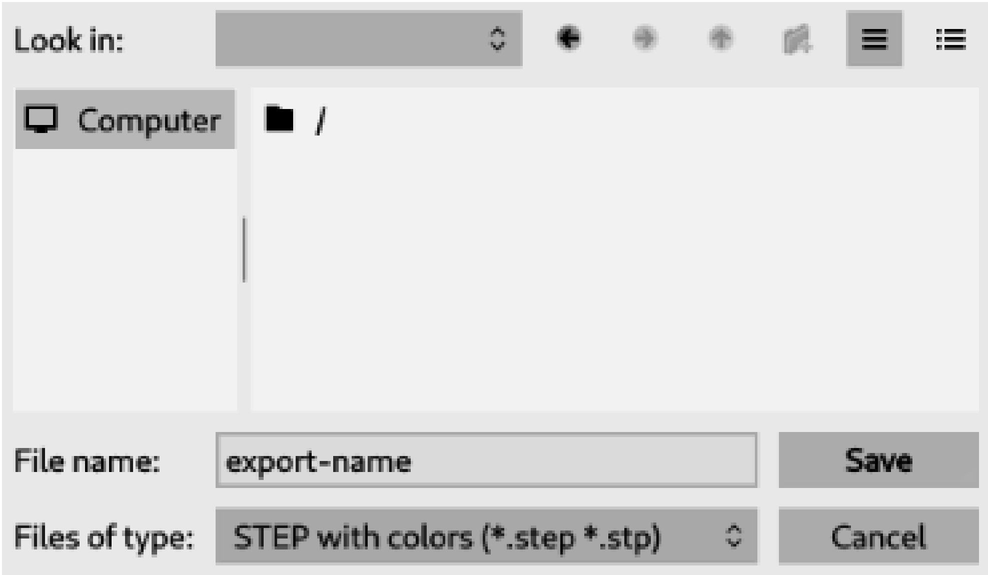


Figure 3. FreeCAD export window.

1. Import CAD file

To start the conversion process the CAD file has to be imported into the software first.

- Start PiXYZ and press `FILE->IMPORT_MODEL` from the toolbar.
- Find and select the desired CAD file.
- Press `OPEN`.

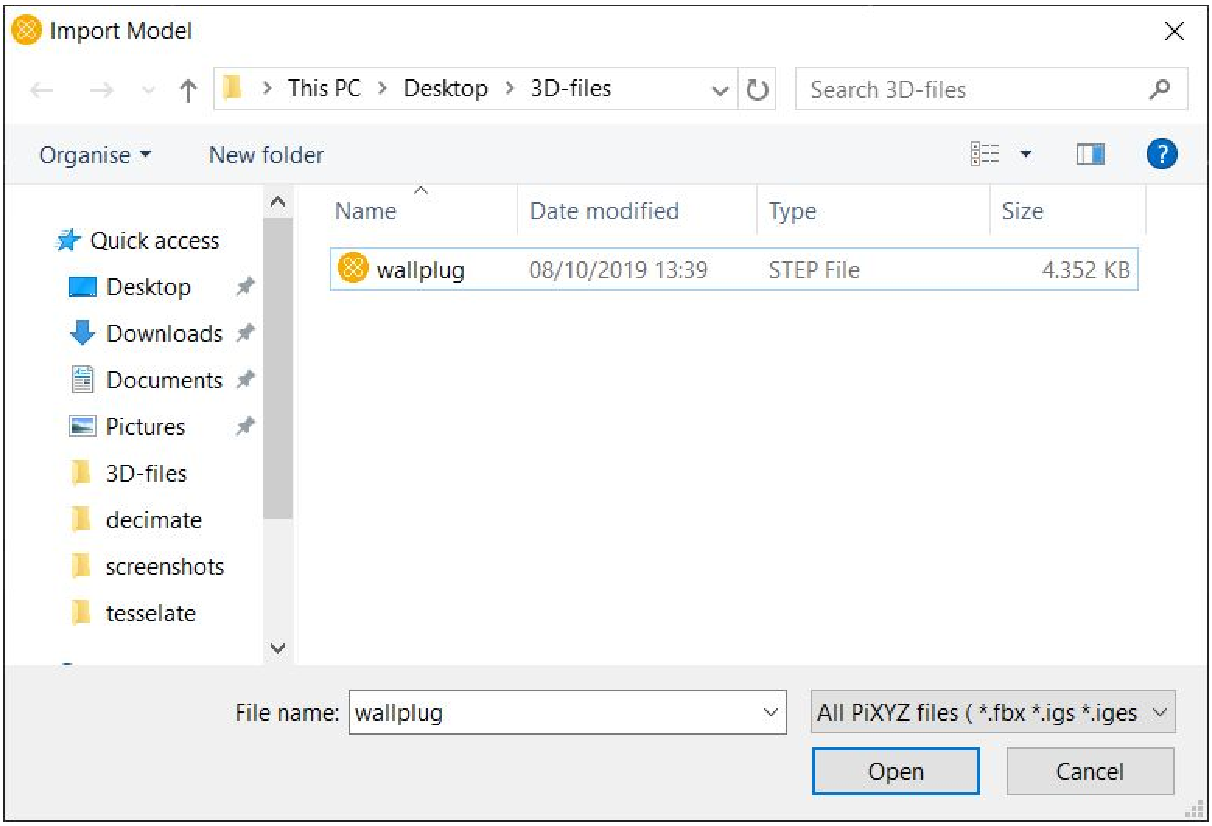


Figure 4. PiXYZ import window.

2. Triangulate

This stage converts the NURBS surfaces of a CAD model to a triangulated mesh. Several parameters can be adjusted to influence the final amount of detail. Because PiXYZ is fast at converting geometry, an initial run is done to see how the model looks like using the medium preset. For more information please refer to *Chapter 3.1*, especially *3.2.1*.

- Open the tessellation window by clicking `CAD->TESSELLATE`.
- Select the medium preset.
- Press `EXECUTE`.

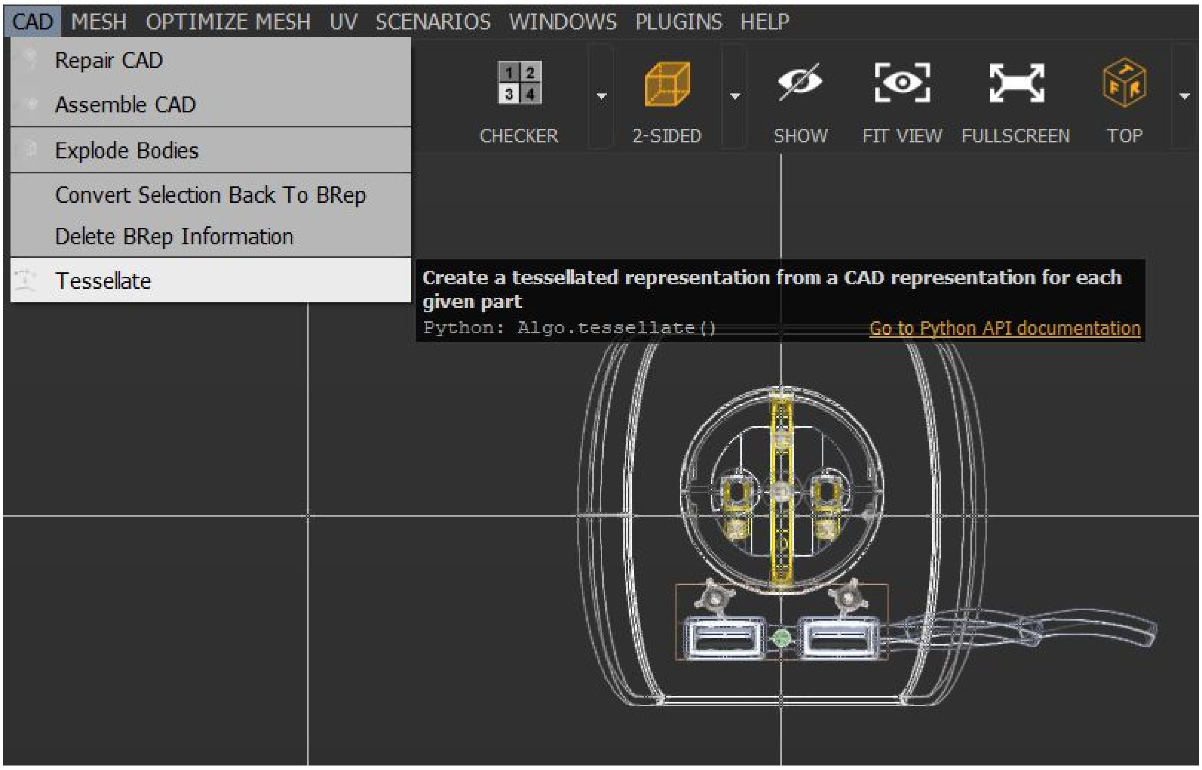


Figure 5. PiXYZ CAD toolbar.

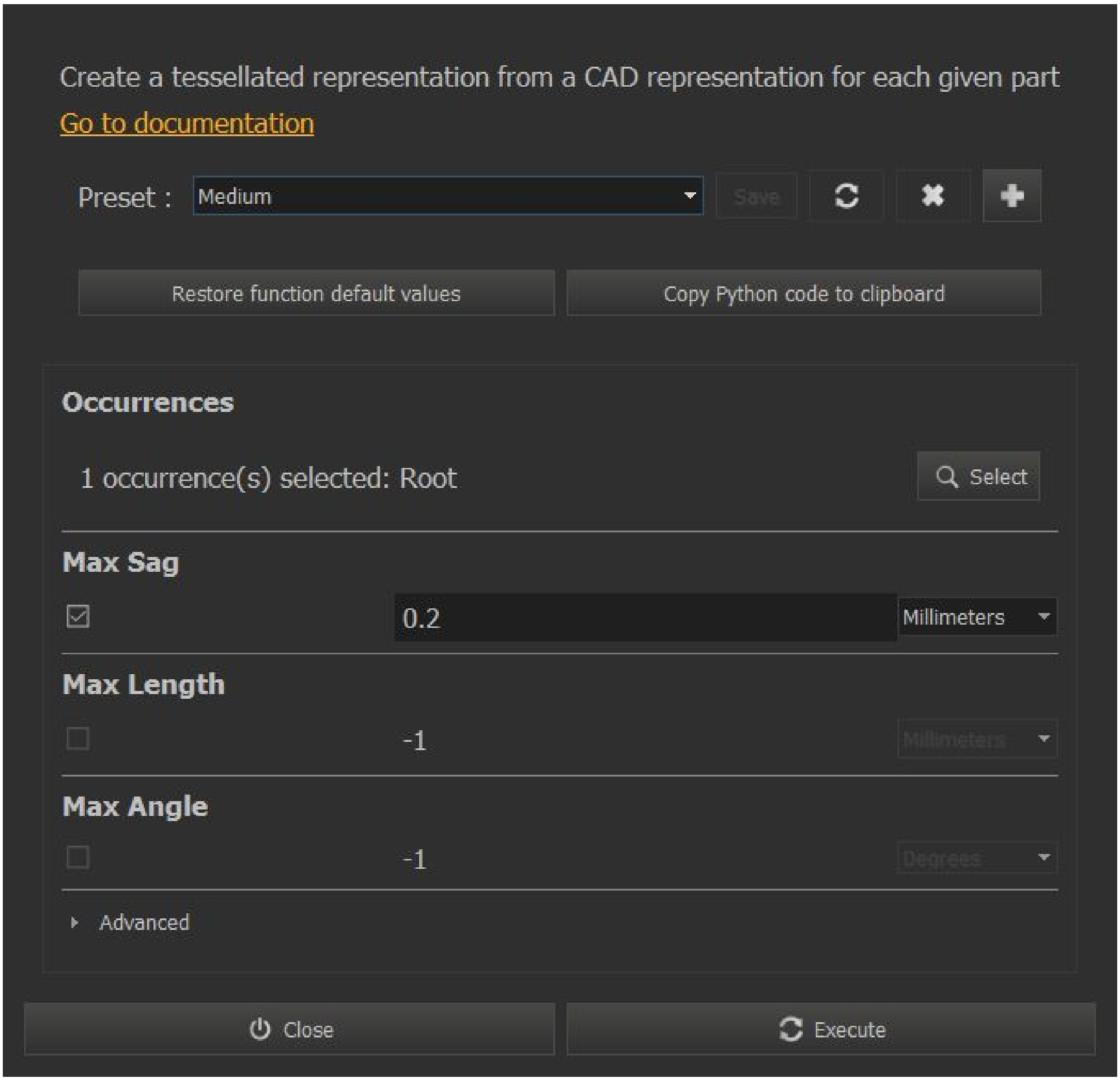


Figure 6. PiXYZ tessellate window.

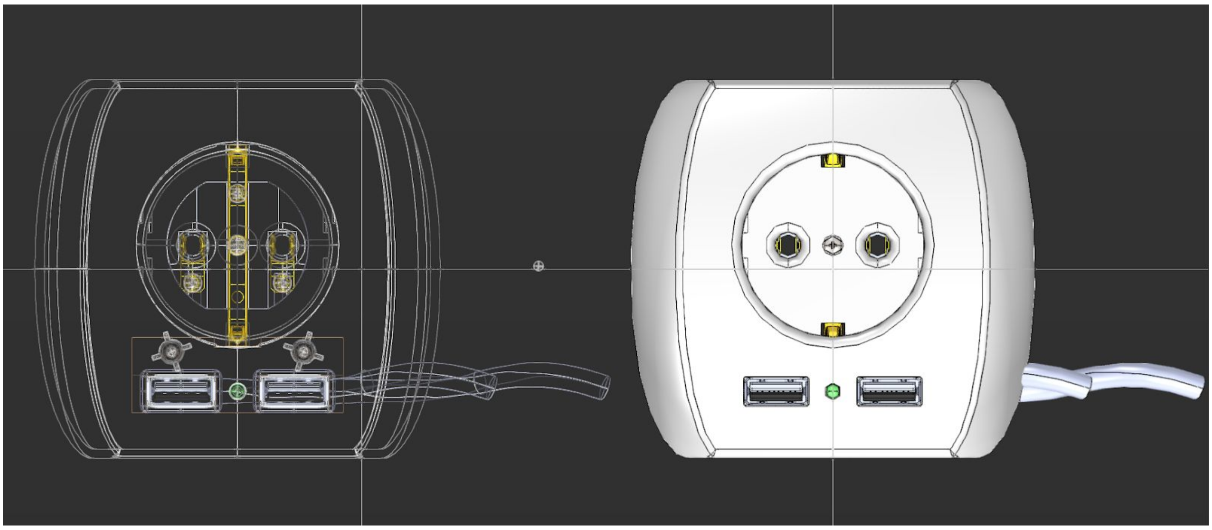


Figure 7. Before (left) and after (right) tessellation.

3. Optimize

3.1 Remove unnecessary components

After having triangulated the CAD geometry, it is now possible to select the parts that are irrelevant for the final look like screws and internal parts. These can either be selected using:

- Manually clicking on parts in the occurrences window
- Manually clicking on the parts in the editor window
- Any of the selection tools shown in Figure 8 under the `SELECTION` toolbar

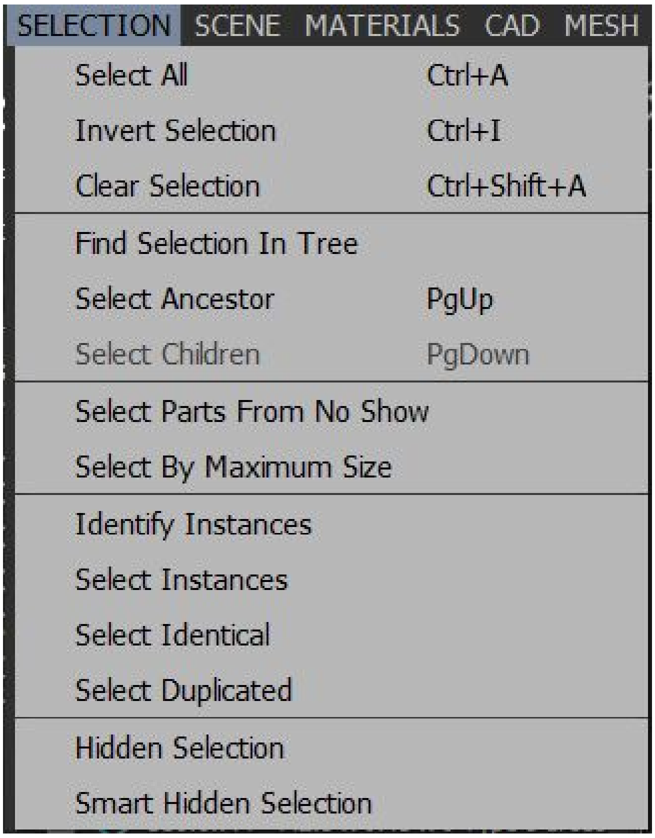


Figure 8. PiXYZ selection toolbar.

After selection, hide the parts that are deemed unnecessary.

Hint: use the **H** and **S** shortcuts to hide and show selected parts, respectively.

Note: in any other software solution, it would be better to execute remove unnecessary components before triangulation. This is to save time by skipping the triangulation process for unnecessary parts. However in PiXYZ, it is difficult to identify parts before triangulation as the CAD geometry shows up as a wireframe (which can be seen in Figure 7 on the left). But since PiXYZ is very fast at triangulation this doesn't matter.

3.2 Retriangulate different components

To optimize the converted CAD model as much as possible, it is recommended to retriangulate different components with different settings to find the right optimization balance for individual components. Creating and using presets may significantly speed up this process. The RE-TESSELLATE-SELECTION function opens the tessellation window which can be seen in *image 5*. The operation can be performed by right clicking on selected parts under the occurrences tab and navigating to RE-TESSELLATE.

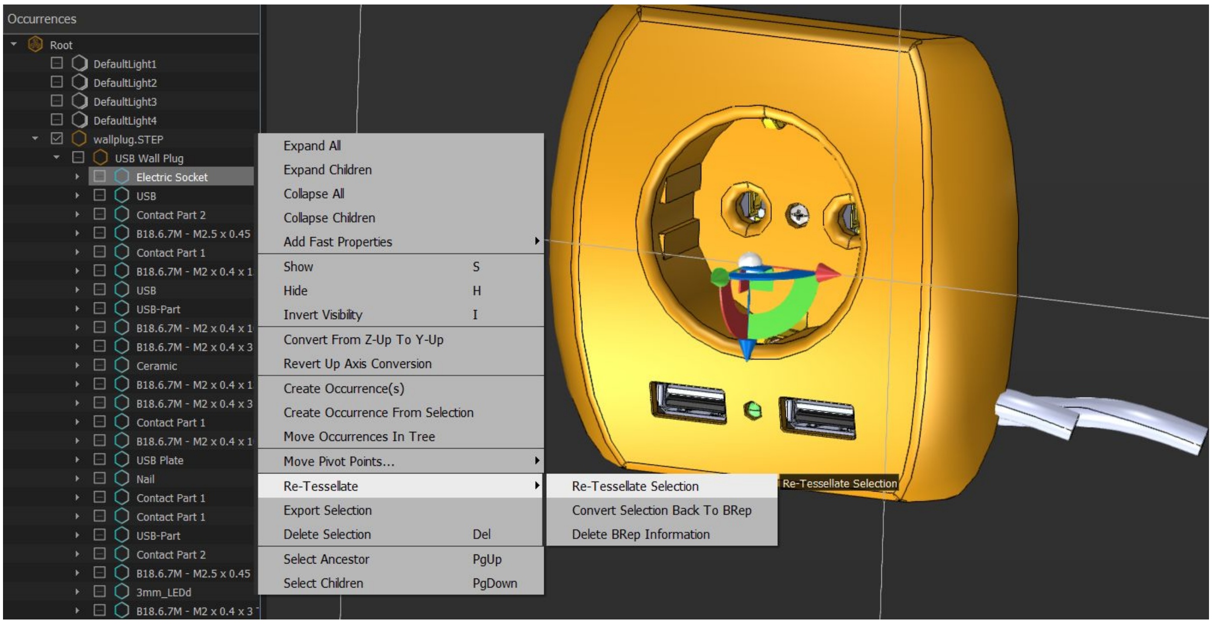


Figure 9. Re-Tessellate Selection.

Note: this is mostly applicable to components of which geometry contains round shapes. Straight edged components won't be affected as much.

Hint: since components are subdivided into more sub-components, re-tessellating every component would be impractical in the case of highly detailed models. Re-tessellating the "parent" parts will automatically re-tesselate their "children" in the occurrences hierarchy. This can save a lot of time.

3.3 Decimate

Decimating is a traditional 3D modeling technique that is used to reduce complexity of a surface mesh. However, this technique does not take the topology of the original CAD geometry in mind and uses approximation. This is great for shaving off some unnecessary complexity after the triangulation algorithm, but should not be relied on too much.

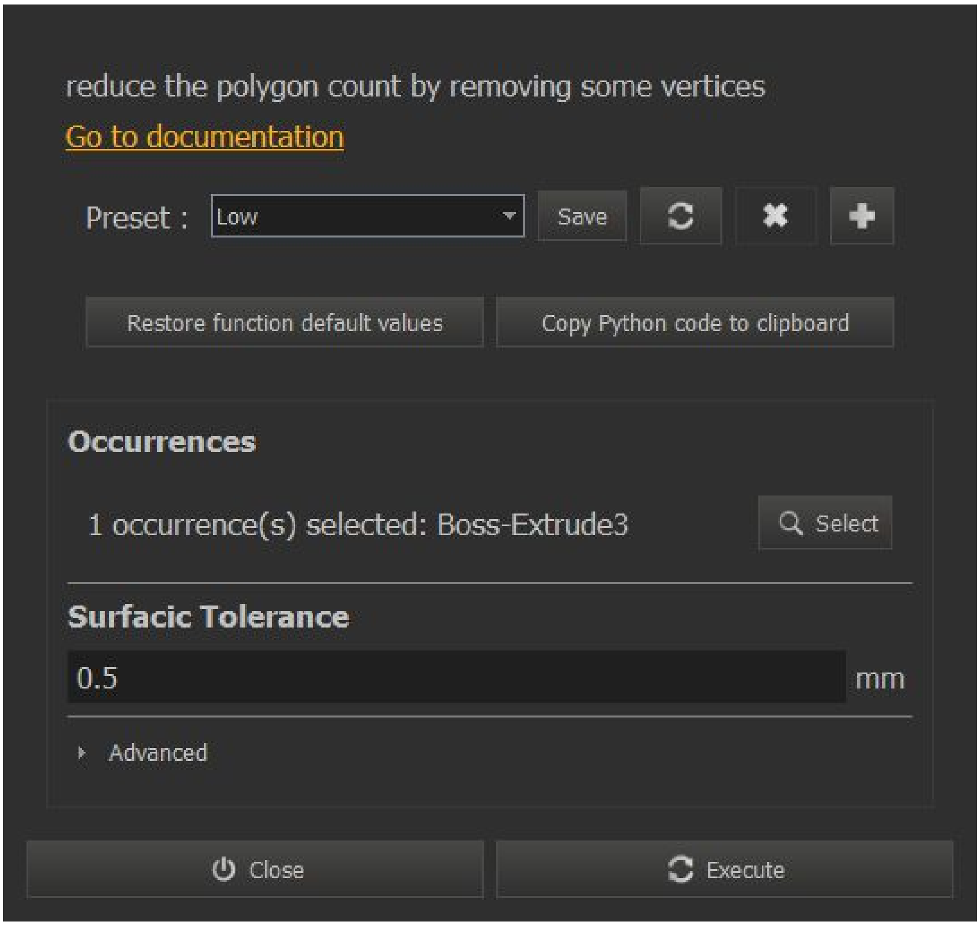


Figure 10. Decimate Window.

3.4 Remove internal geometry

For some use cases it is not important to render parts that are inside the CAD model and not visible from the outside. In that case the geometry inside of the CAD model should be removed. PiXYZ has a feature that can automatically do this per triangle, which is found under `OPTIMIZE MESH->HIDDEN REMOVAL`. However, this is quite an expensive operation and therefore should be done last. Some parameters can be set to increase the precision of this process. Beware that this can drastically increase the required time of this operation.

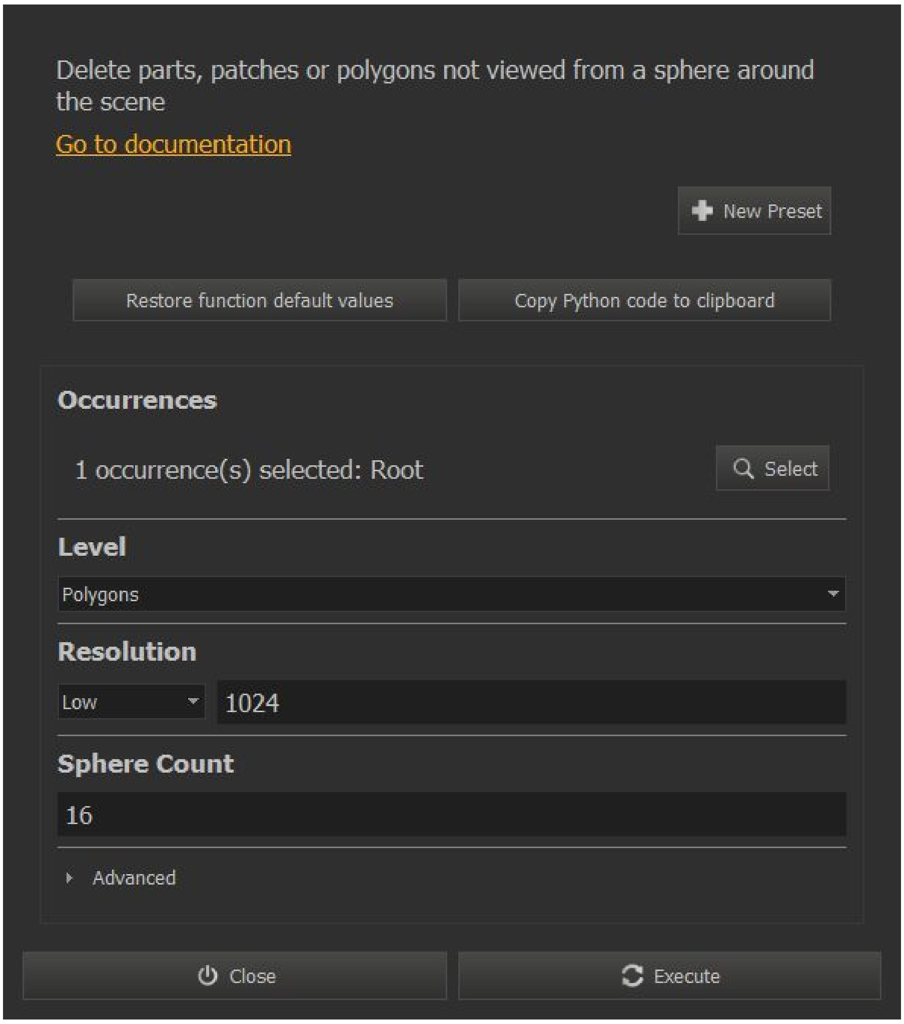


Figure 11. Remove internal geometry window.

4. Texture

For a realistic final look textures should be applied to the 3D model. PiXYZ has the functions that can do this automatically without manual intervention. Although all 3D modelling software can be used for texturing, PiXYZ makes it a lot easier due to it being specifically made for ease of use. Normally texturing is a difficult process that has to be done by a 3D artist. But because CAD models are usually separated by their components, textures can be applied per component. PiXYZ pipeline allows CAD data to be used for specifying texture properties.

4.1 Import materials

The first step is to import materials, e.g. metal, plastic and wood. These materials can be applied to multiple components. A material can be created through the Material Editor, which can be opened through the toolbar `MATERIALS->MATERIAL EDITOR`. For more information on materials, refer to *chapter 3.2.2*.

- Press `ADD` to create a new material.
- select the desired type of material (if unsure, choose standard).

After having created a new material textures should be assigned. In the example given in Figure 12, a standard material will be used. Standard materials have multiple textures like diffuse, specular and shininess. Each of these channels either accepts a single value (that is used for the whole material) or a texture. Initially, each channel is set to COLOR.

- Click on the drop down arrow next to COLOR and select TEXTURE. Now an empty image slot is shown as UNDEFINED.
- Click on the empty image slot that is shown as UNDEFINED. This opens the TEXTURE LIBRARY window, through which images can be loaded that are used as textures.
- Click on the desired texture to be loaded in the slot and press SELECT like in Figure 13.

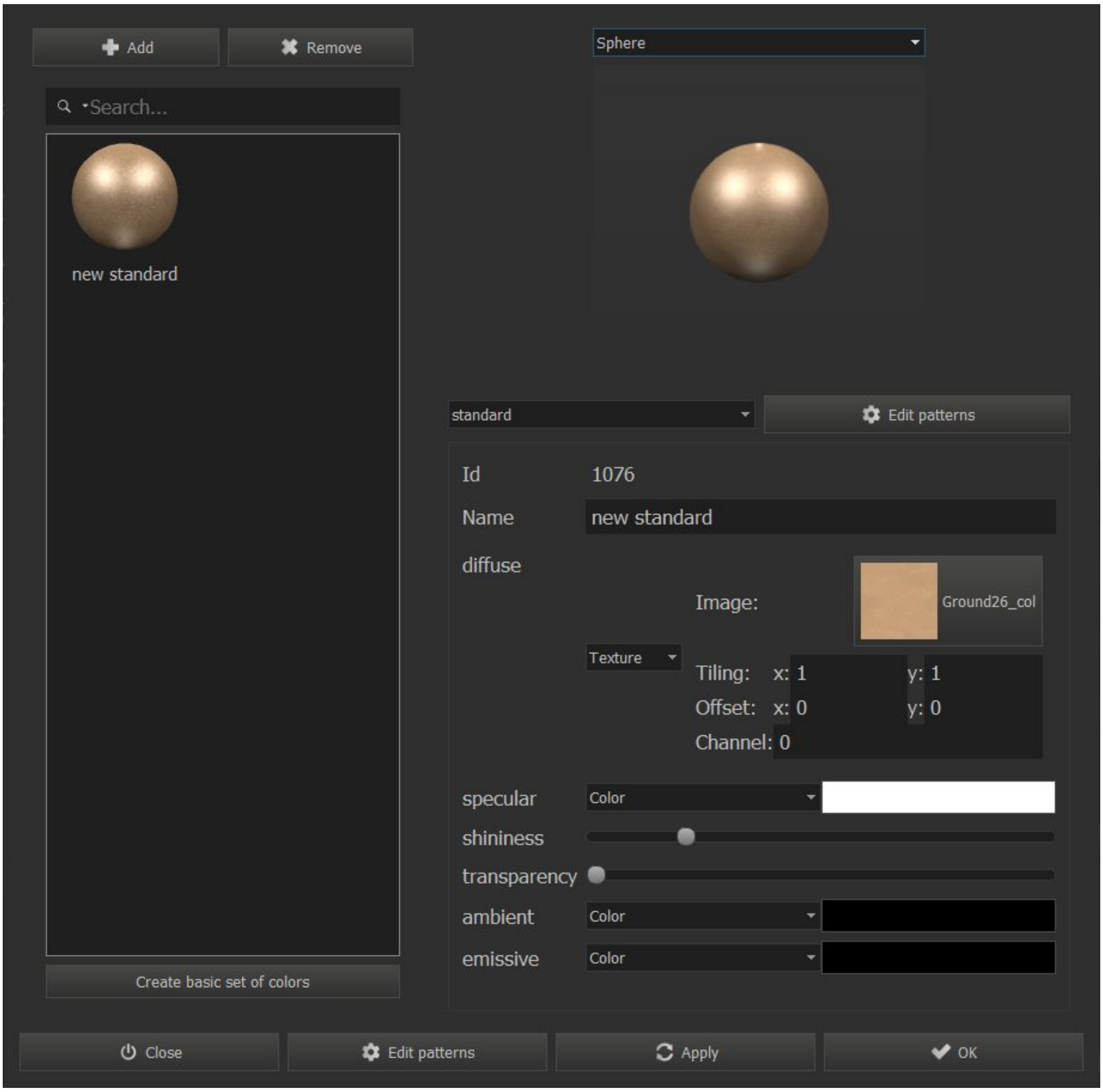


Figure 12. Material editor window.

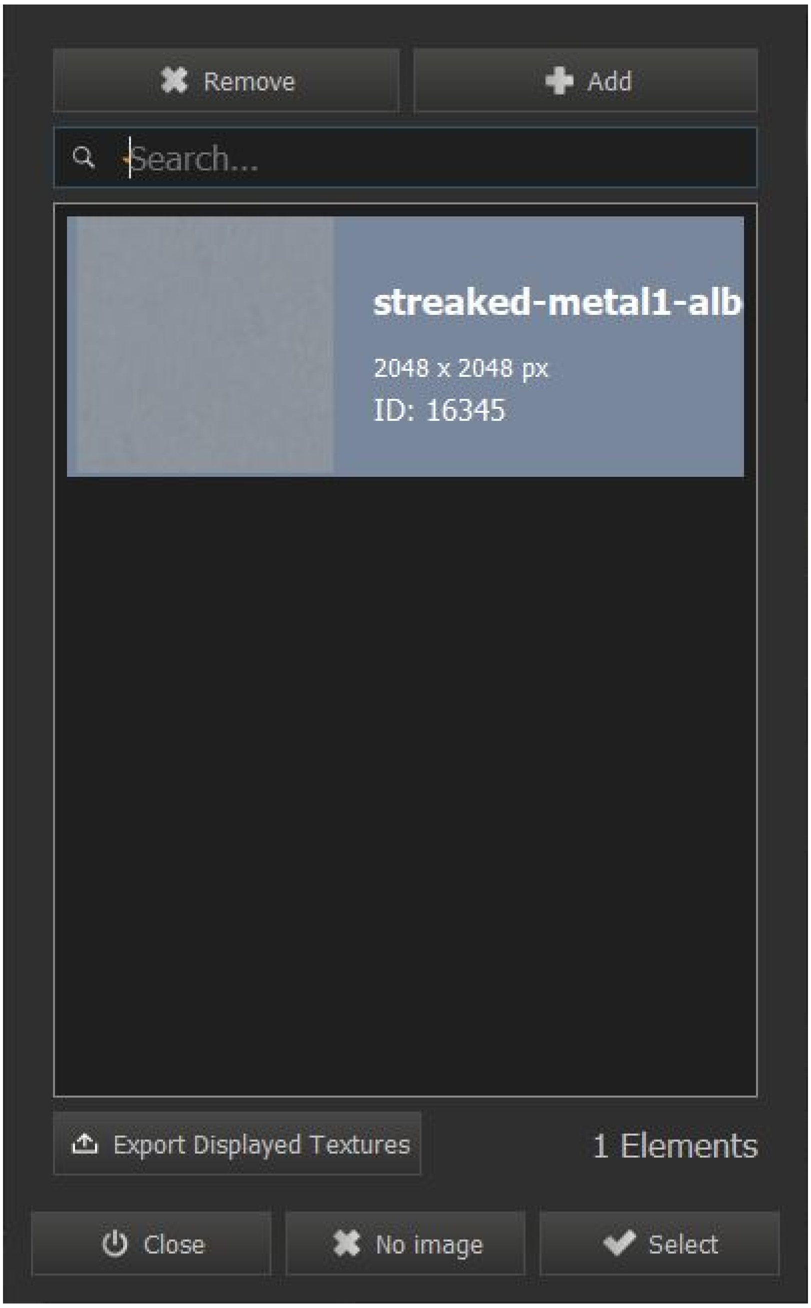


Figure 13. Texture library window.

4.2 UV mapping

UV mapping is a technique that maps materials to a mesh. Unwrapping can be done automatically in PiXYZ using any of the functions under `UV->GENERATE UV BY PROJECTION`. The only parameter that has to be changed is the UV 3D size, which determines how stretched the material is on the surfaces. An example of the window is shown in Figure 13.

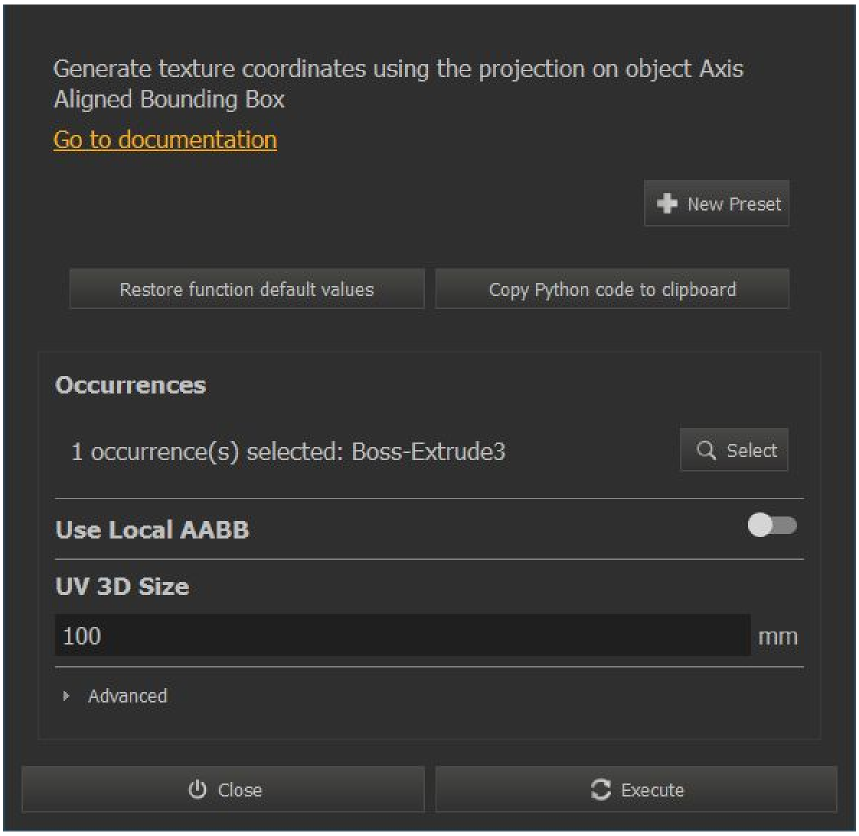


Figure 14. Map UV on AABB.

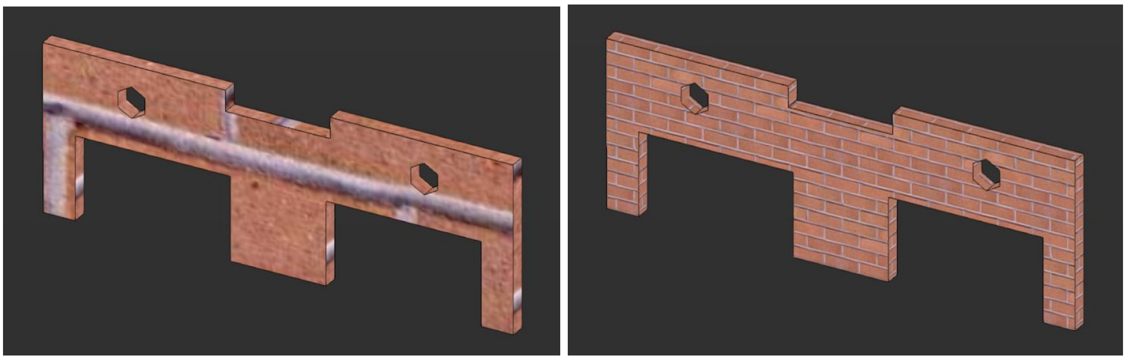


Figure 15. UV mapping using low (left) and high (right) UV 3D size.

4.3 Apply materials

Finally, after UV mapping the materials can be applied. This is done through the inspector after clicking on a component. Click on `NO_MATERIAL` button, which opens the material selector as shown in Figure 17.

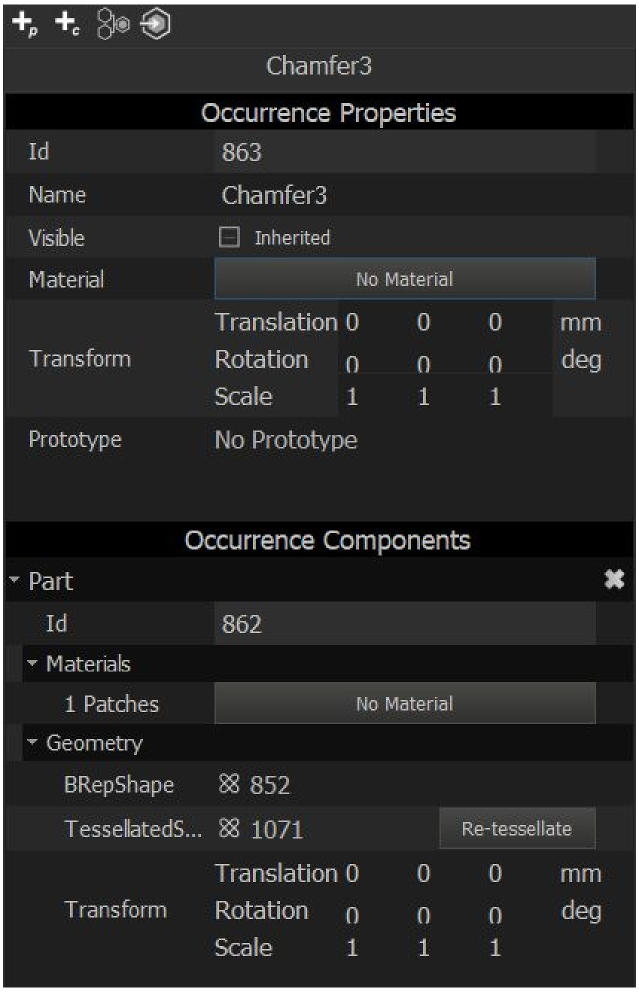


Figure 16. Inspector.

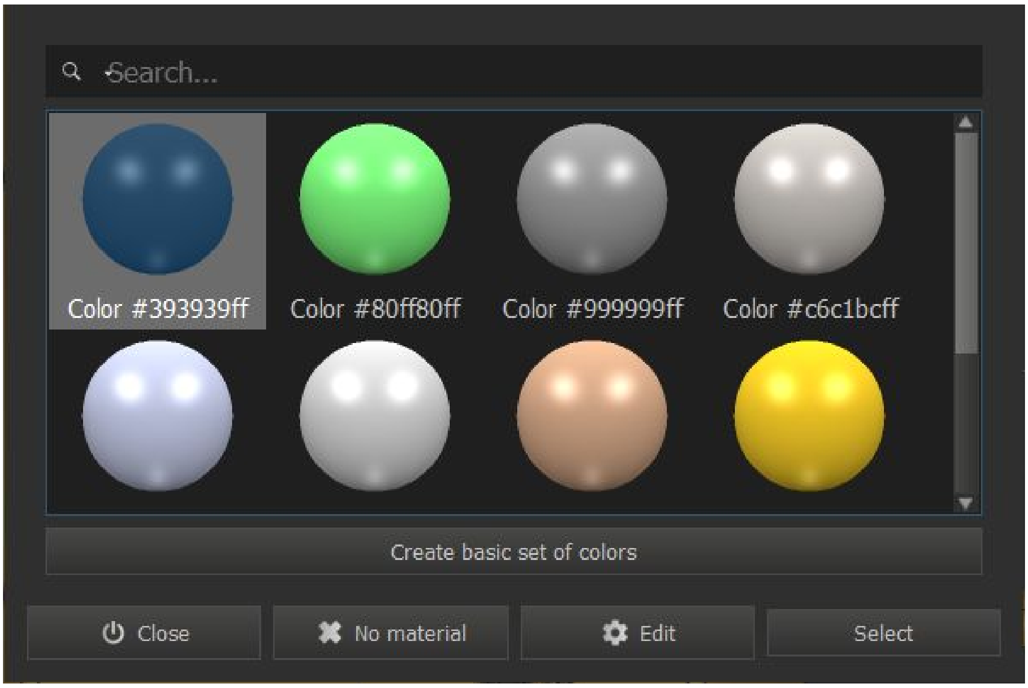


Figure 17. Material selector window.

5. Export

Once the model has reached satisfactory standards in terms of performance and looks, the last remaining step is to export it to suitable format. Most commonly this format will be FBX or OBJ. For more information about the difference in file types please refer to chapter 3.1 in the theoretical paper.

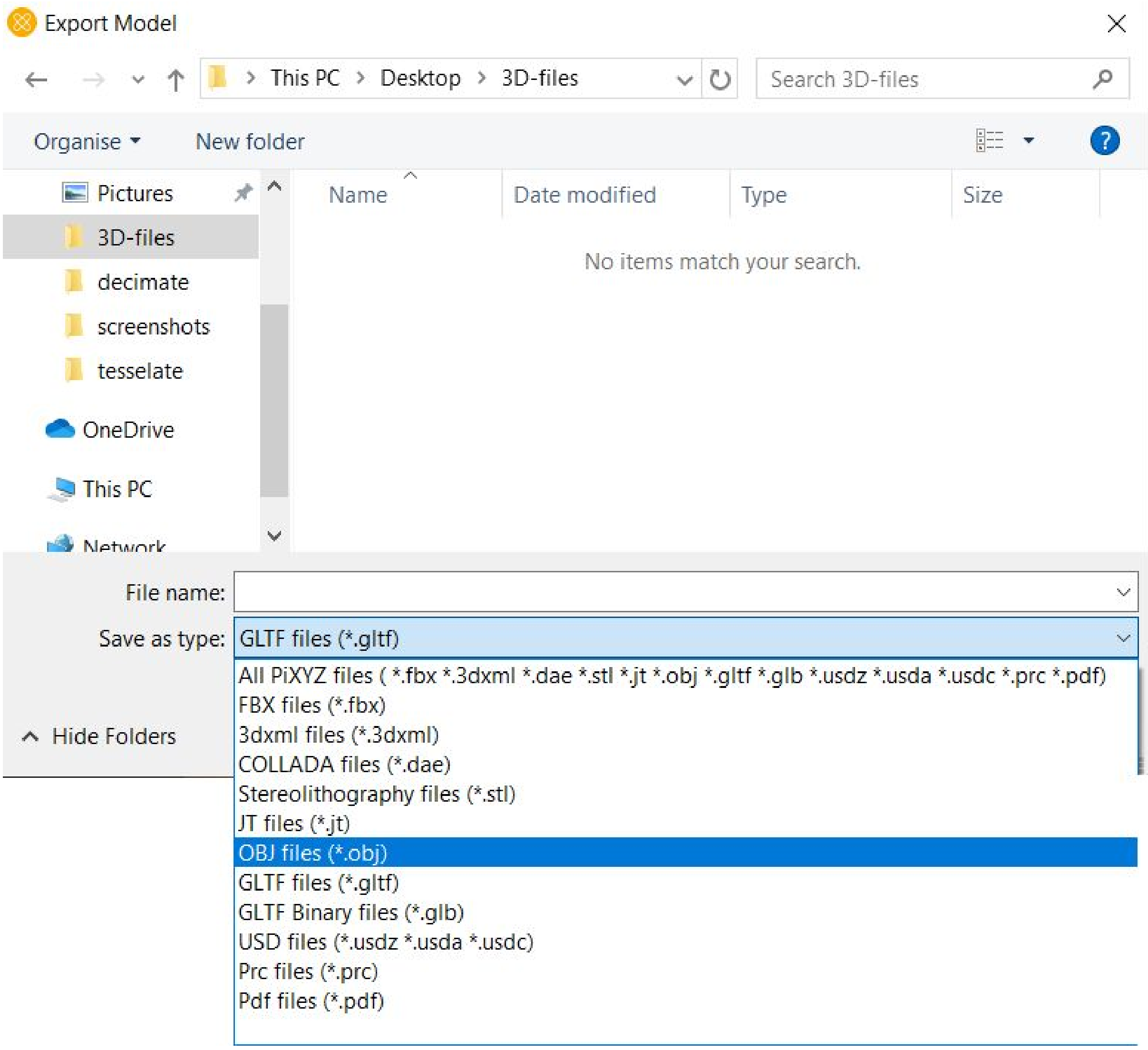
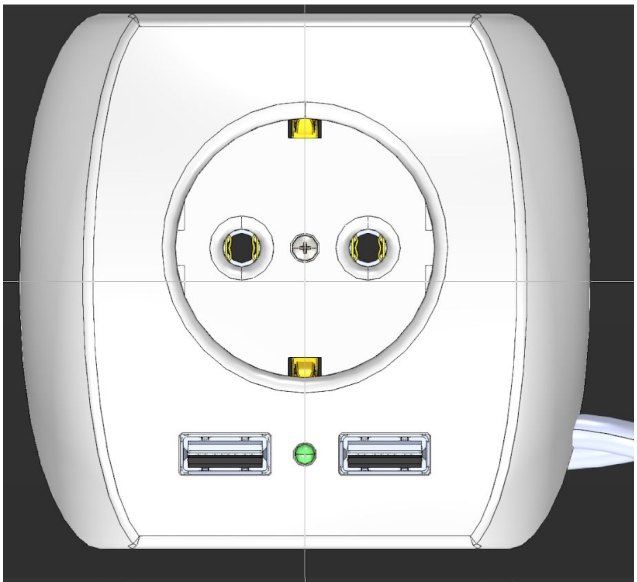


Figure 18. Export window.

Tests

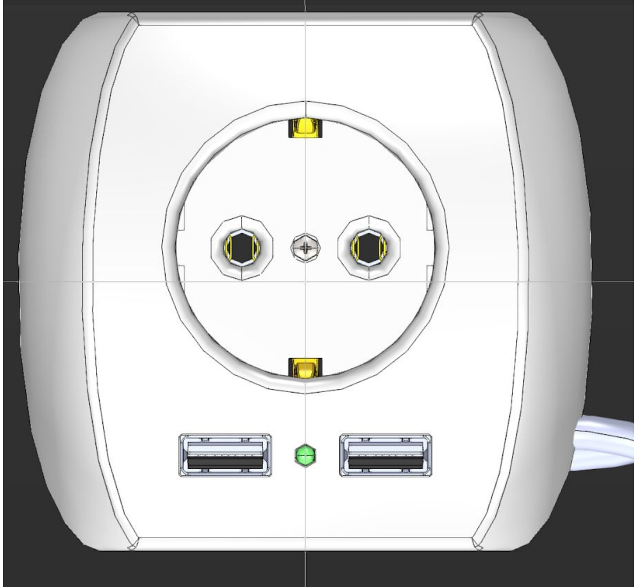
1



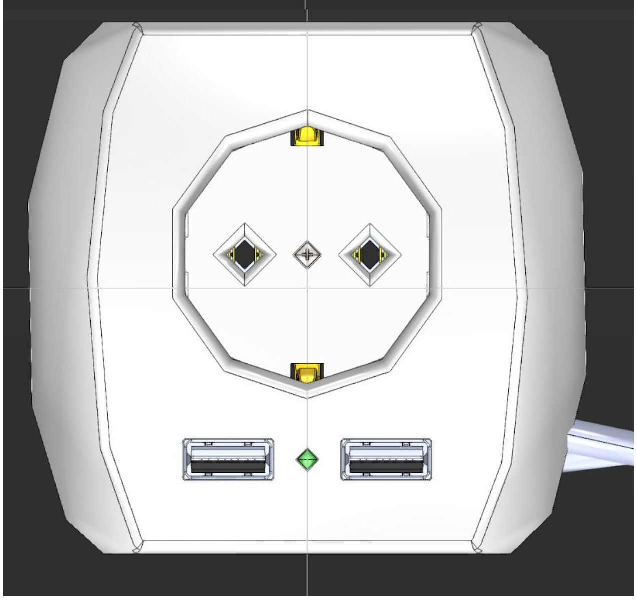
Test	Triangles	Max sag
1	9118	0.1
2	7292	0.2
3	5638	1

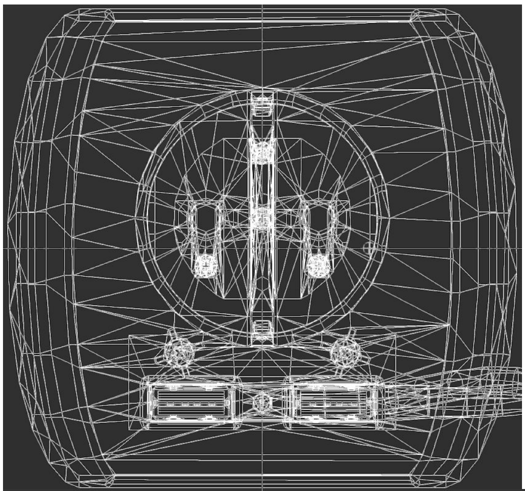
Table 1. Triangulation tests.

2



3

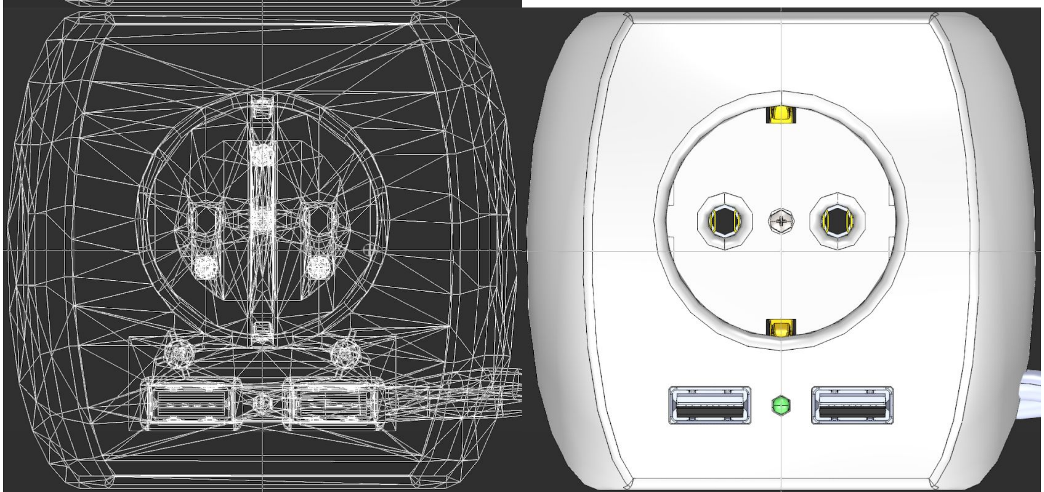




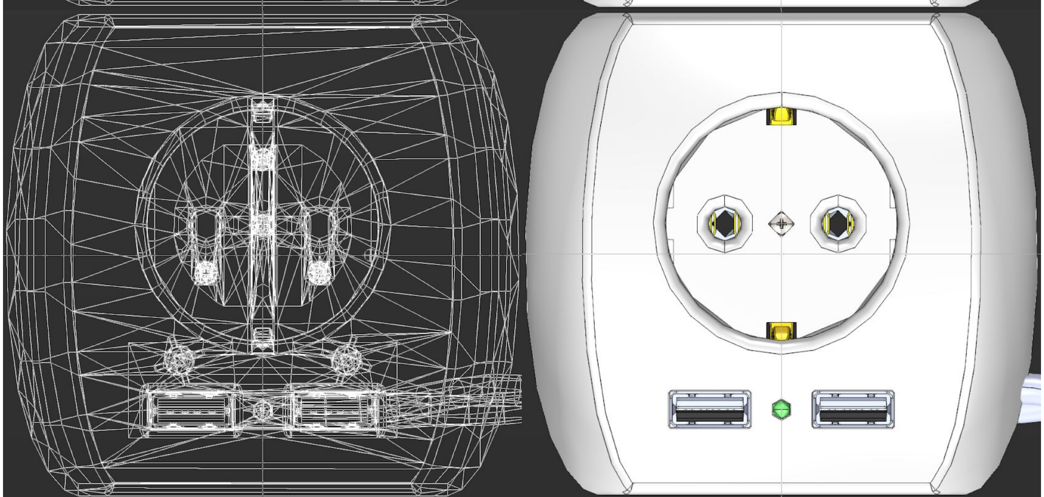
Original (Test 2 of triangulation, 7292 triangles)

Test	Triangles (optimize %)	surfacic	lineic	normal
1	6968 (4.4%)	0.5	0.1	1
2	6400 (12,2%)	0.7	0.7	5
3	5948 (18,4%)	1	off	8

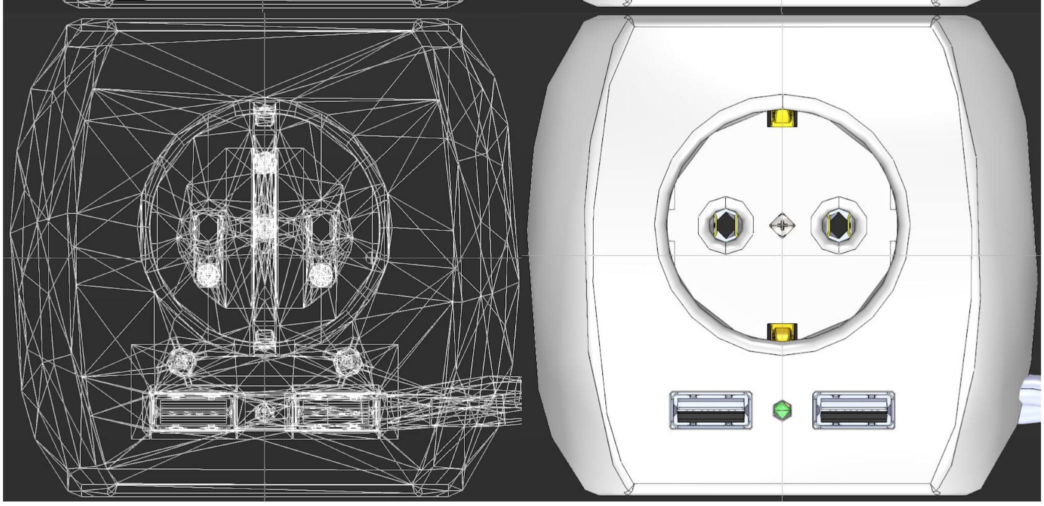
Table 2. Decimation tests.



1



2



3

Sample script

```
#--------------------------------------------------------
#    Script PiXYZ STUDIO - Run Generic Process
#
#    This Python script is meant to be used in PiXYZ STUDIO
#    Open the script in STUDIO Script window, and click the Execute button (CTRL+E)
#
#     This script is an APPROXIMATE version in Python of the scenario RUN GENERIC PROCESS available in the SCENARIOS menu
#      See the API documentation for more information on that specific scenario, and on all the unitary algorithms used below
#
#    Copyright PiXYZ Software - 2019
#--------------------------------------------------------

OVERRIDE_EXISTING_UVs=False
REPACK_UVs=False
MAP_SIZE=1024
MAP_PADDING_REPACK=1

#Deletes hidden parts (visibility off)
scene.selectPartsFromNoShow()
scene.deleteOccurrences(scene.getSelectionedOccurrences())

#Merges parts located in final assemblies in the Product Structure (tree)
scene.mergeFinalLevel()

#Compresses the tree
scene.compress

#Gets scene root node
root = [scene.getRoot()]

#If mesh models are present in the scene (by opposition to CAD models), UVs are created by projection on channel 1, if required (OVERRIDE_EXISTING_UVs=True)
algo.mapUvOnCubicAABB(root, 100, 1, OVERRIDE_EXISTING_UVs)

#Repairs CAD models if present in the scene (does nothing otherwise)
algo.repairCAD(root, 0.1, False)

#Creates meshes out of CAD models if present in the scene (does nothing otherwise), with automatic UV generation (based on CAD faces) on channel 1
algo.tessellate(root, 0.15, -1, -1, True, algo.UVGenerationMode.UniformUV, 1)

#Repairs meshes
algo.repairMesh(root, 0.1)

#Deletes patches on the meshes prior to decimate them
algo.deletePatches(root)

#Deletes lines, useless for export
algo.deleteLines(root)

#Decimates meshes to optimize polygon count
algo.decimate(root, 1, -1, 1)

#Creates UVs by projection on channel 0 for the meshes created out of CAD model, if required (OVERRIDE_EXISTING_UVs=True)
algo.mapUvOnCubicAABB(root, 100, 0, OVERRIDE_EXISTING_UVs)

if REPACK_UVs:
        algo.repackUV(root, 1, True, MAP_SIZE, MAP_PADDING_REPACK, True, 3)
```