

Technische Universität München

BGCE Project: CAD – Integrated Topology Optimization

BGCE First Milestone Meeting

S. Joshi, *J.C. Medina*, *F. Menhorn*, S. Reiz, B. R  th, E. Wannerberg, A.
Yurova

November 2, 2015



Contents

1. Introduction

- 1.1 Contents
- 1.2 Motivation
- 1.3 Workflow Overview
- 1.4 Schedule & Milestones
- 1.5 Organization
- 1.6 Organization

2. Topology optimization

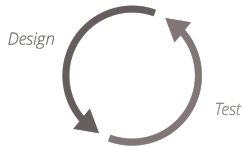
- 2.1 Status
- 2.2 The user's view
- 2.3 The internal view
- 2.4 Back to the user's view
- 2.5 The next steps MOVE TO LATER

3. Summary

4. Outlook

Motivation

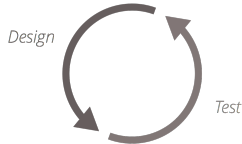
Current Design Process:



- Iterative and redundant
- Time consuming

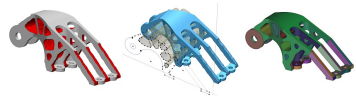
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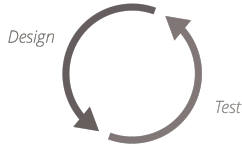
Topology optimization



- Promoted by additive manufacturing

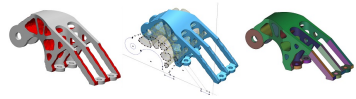
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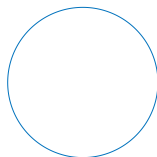
- Promoted by additive manufacturing

Focus:

Convert optimized geometry to **lightweight** and **scalable** CAD formats

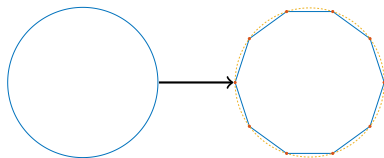
Workflow Overview

CAD design



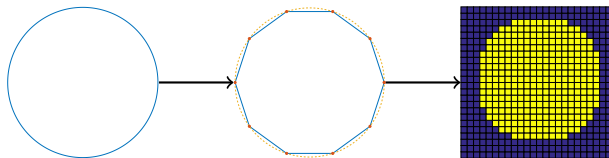
Workflow Overview

STL interface



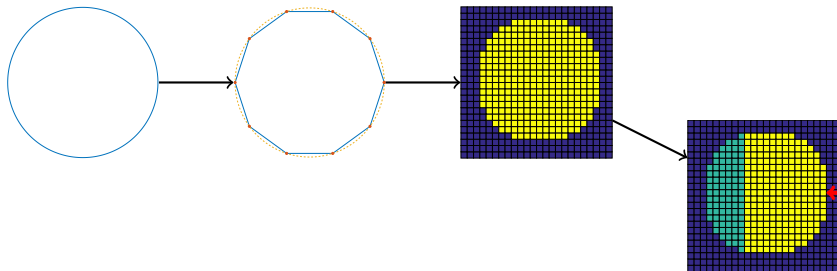
Workflow Overview

Voxelized topology



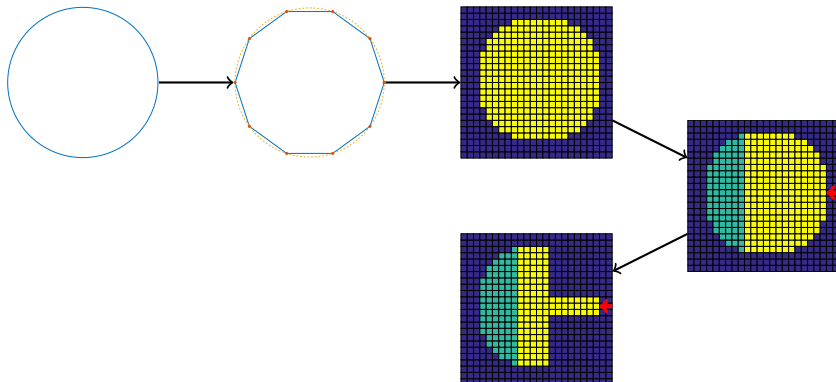
Workflow Overview

Specification of loads and fixtures



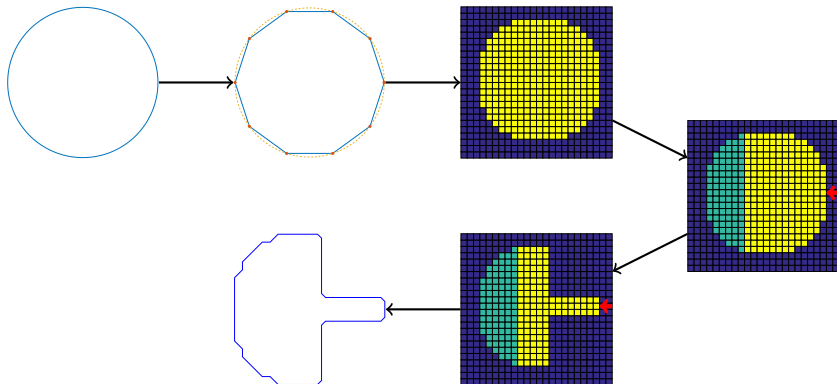
Workflow Overview

Optimized topology



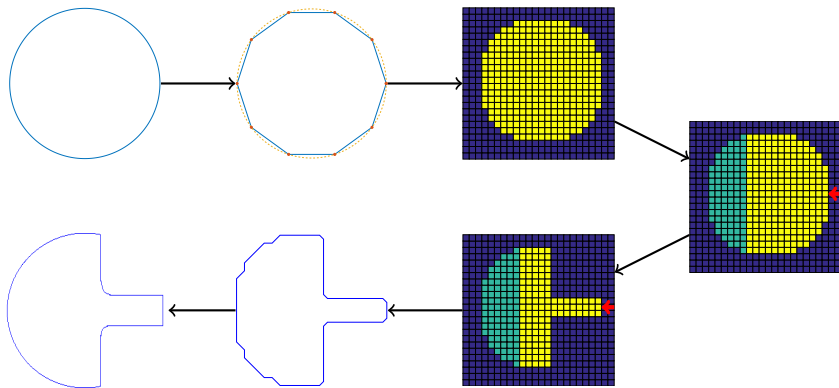
Workflow Overview

Surface extraction

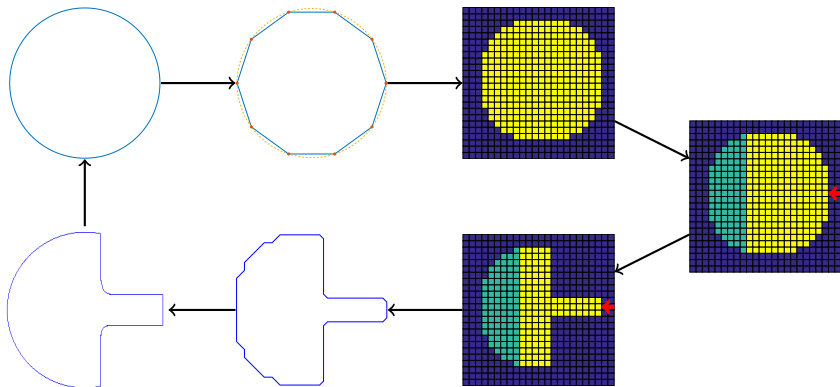


Workflow Overview

Parametrized CAD-geometries

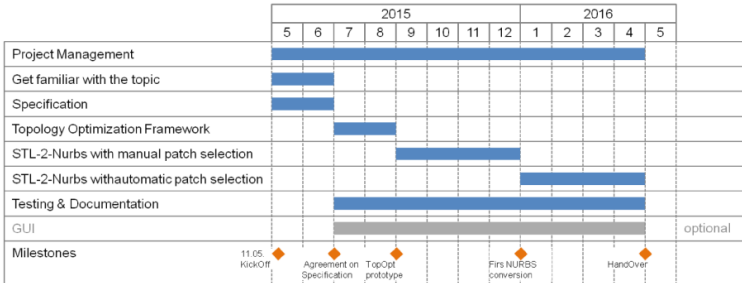


Workflow Overview



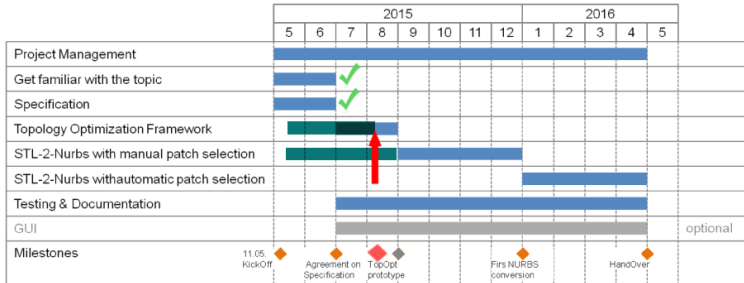
Schedule & Milestones

Schedule:



Schedule & Milestones

Schedule: (current)



Divide and Conquer



Benjamin R  th

Project Manager



Erik Wannerberg

Project Supervisor



Friedrich Menhorn



Saumitra Joshi



Severin Reiz

Topology Optimization



Benjamin R  th



Juan Carlos Medina

Surface Extraction



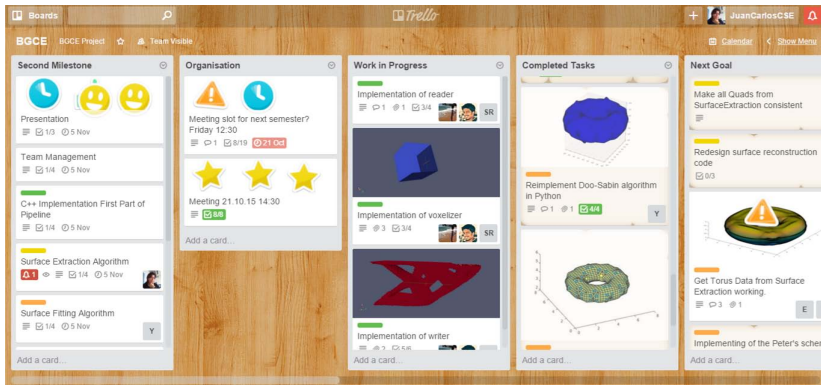
Erik Wannerberg



Anna Yurova

Surface Fitting

Project management



Contents

1. Introduction

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- 1.2 Motivation
- 1.3 Workflow Overview
- 1.4 Schedule & Milestones
- 1.5 Organization
- 1.6 Organization

2. Topology optimization

- 2.1 Status
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- 2.3 The internal view
- 2.4 Back to the user's view
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3. Summary

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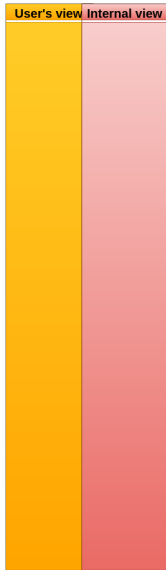
Status DRAFT

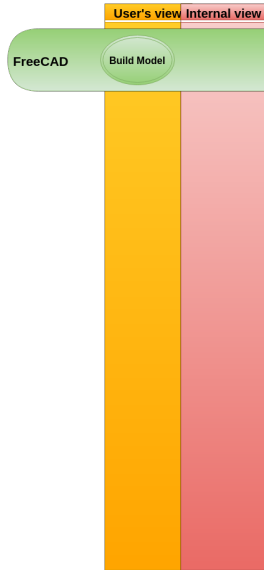
Last milestone

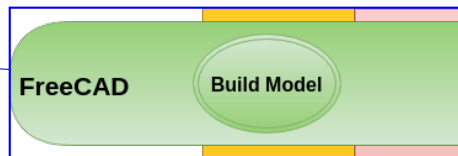
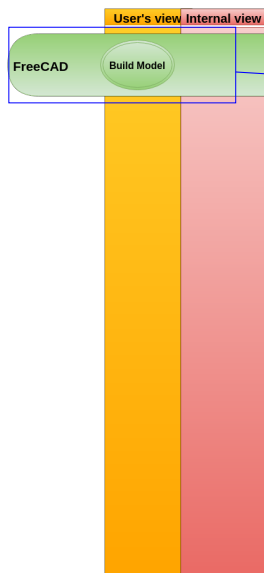
- ✓ Manual voxelization using CVMLCPP
- ✓ "Hard coded" script for ToPy input
- ✓ Topology optimized geometry using ToPy
- ✗ Recognition of boundary conditions

Today

- ✓ Voxelization with OpenCascade
- ✓ Extraction of loads, fixtures and active elements through colouring
- ✓ Automatic "one click" pipeline to surface reconstruction







- Model geometry in favorite CAD tool
- Colour faces for boundary conditions
 - Red** Fixture
 - Green** Active
 - RGB** RGB value in $[0 \leq R < 255, 0 \leq G < 255, 0 \leq B < 255]$ for load vector
- Save model as STEP with Colours and IGES with Colours

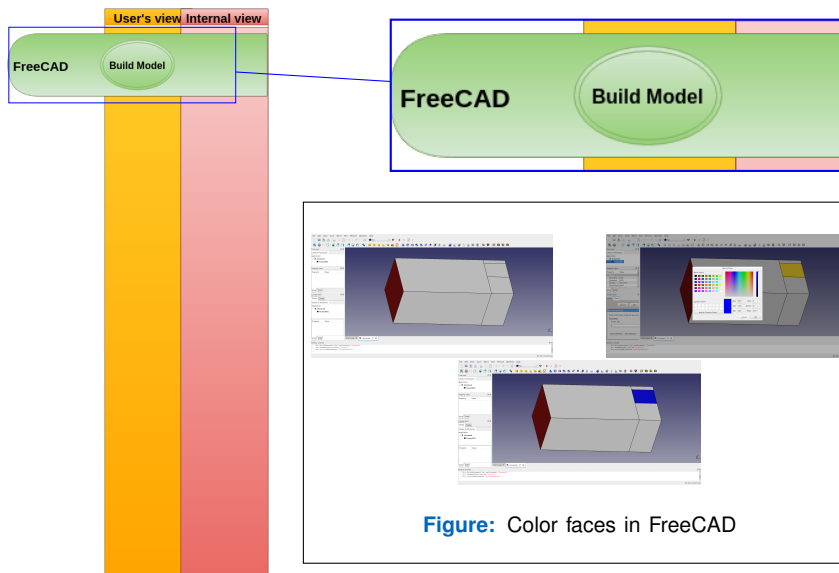
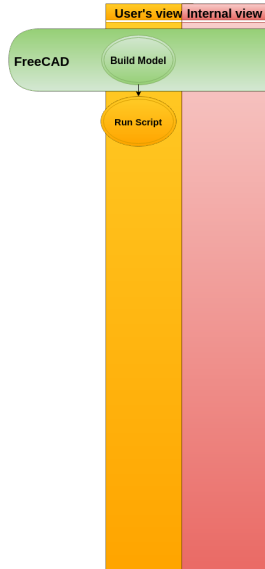
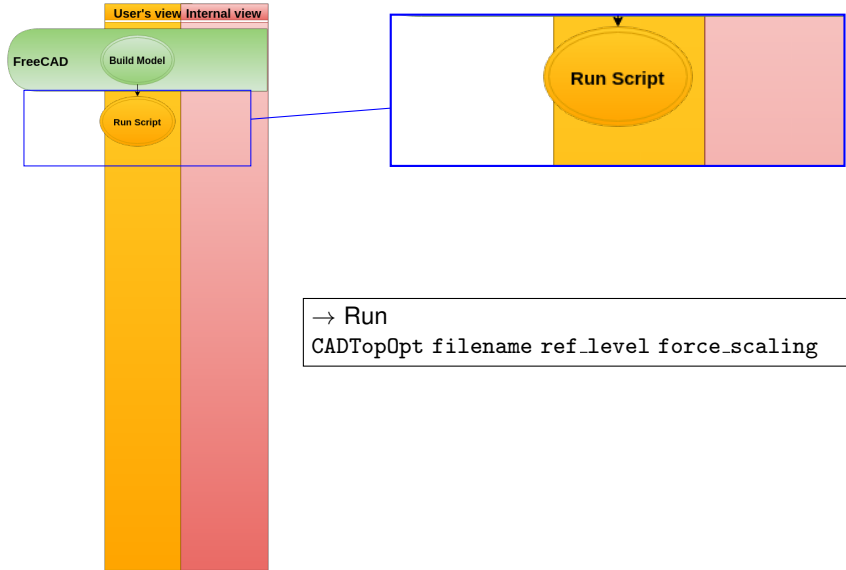
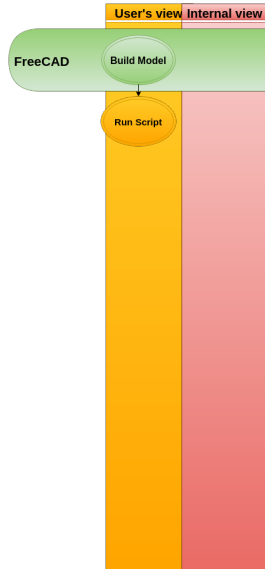
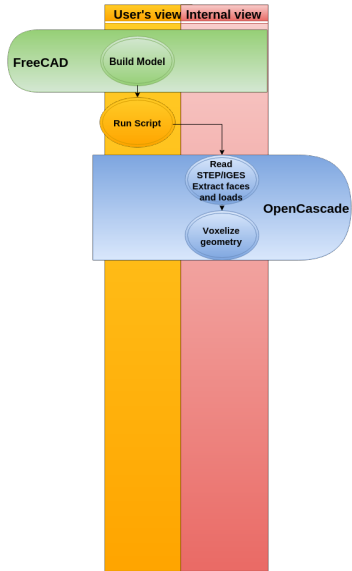


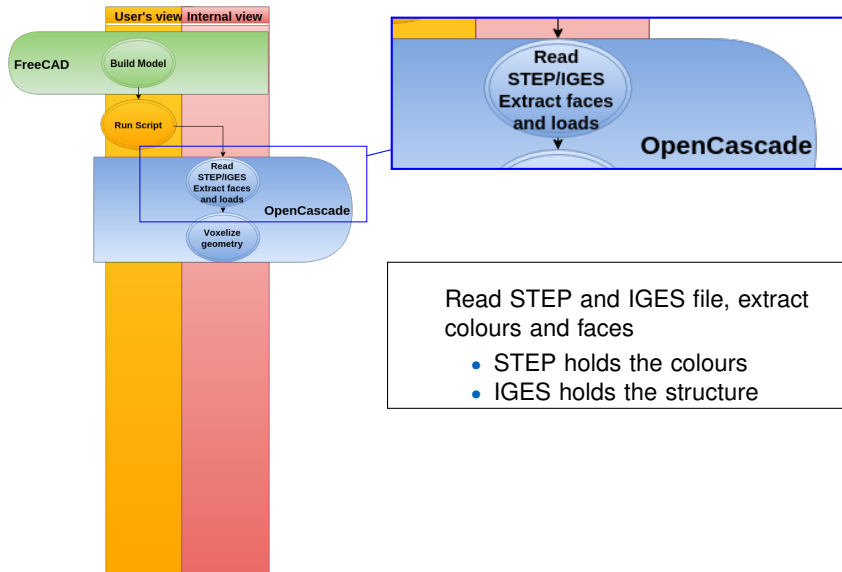
Figure: Color faces in FreeCAD

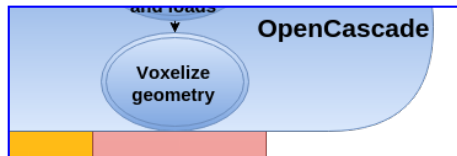
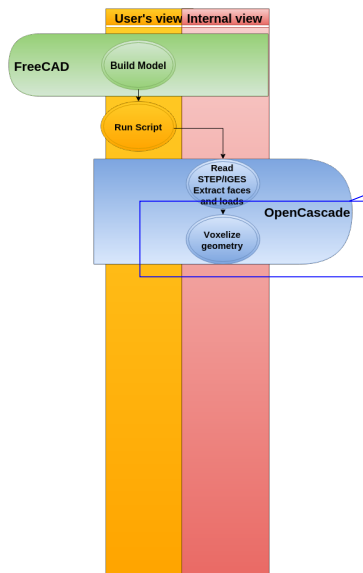












Voxelize faces using OpenCascade

- Included open cascade voxelizer

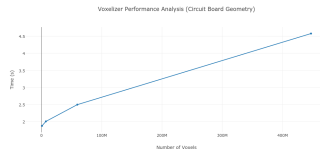
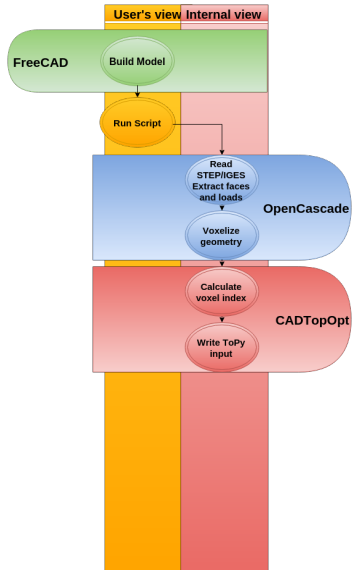
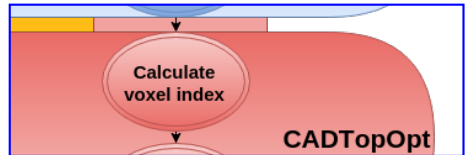
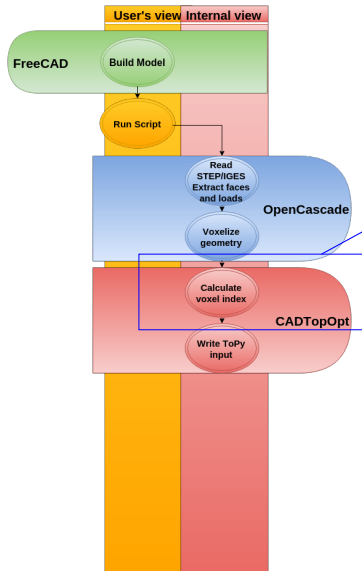


Figure: Scaling of voxelizer

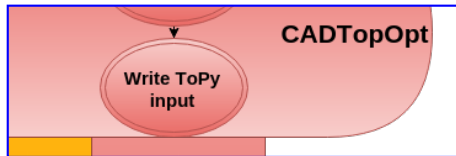
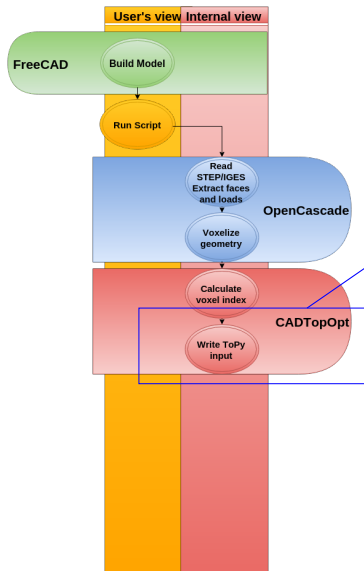




Different indexing for elements and nodes in ToPy

```
#####
### Discretisation of the design domain ###
#####
# 2D: Y          3D: Y
# |             |
# +---X         +---X
#               Z
#
# 1--5--9
# | 1 | 5 |
# 2--6--10
# | 2 | 6 |
# 3--7--11
# | 3 | 7 |
# 4--8--12
#
```

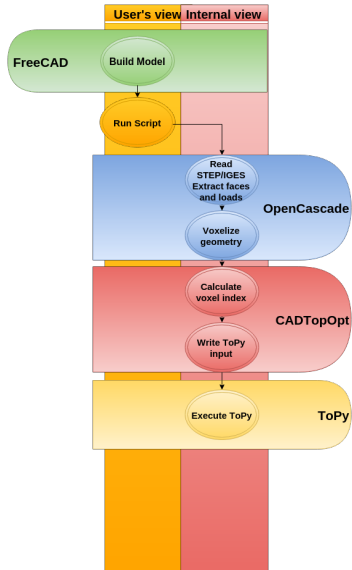
Figure: Indexing in ToPy

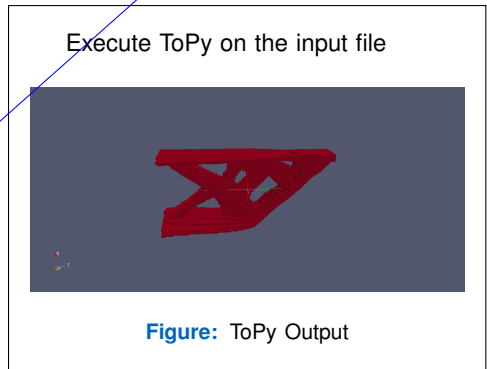
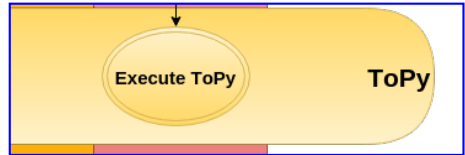
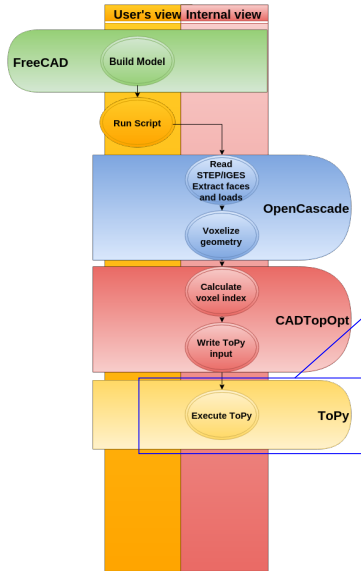


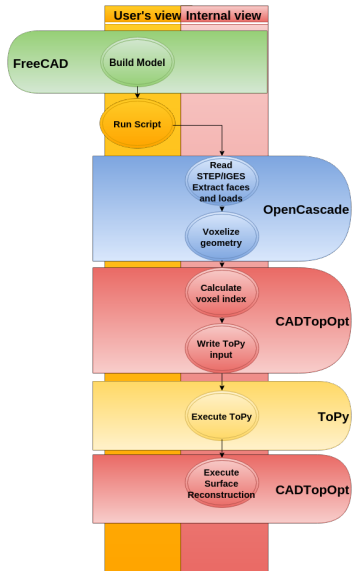
Each voxelindex is specifically written

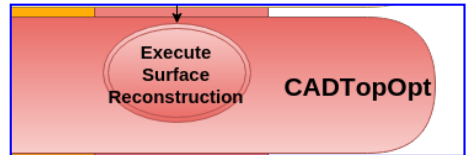
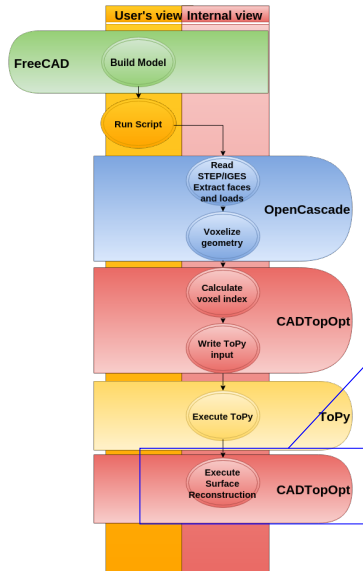
[illegible]

Figure: Script for ToPy









Running dual contouring algorithm

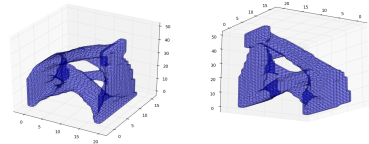
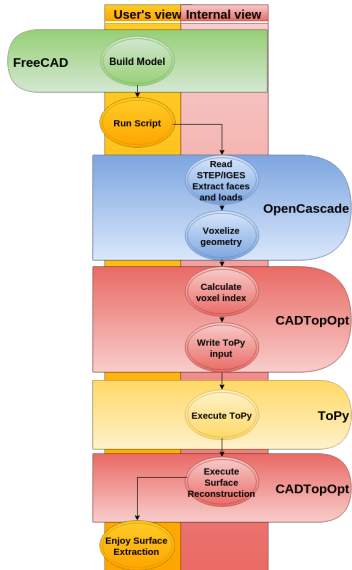
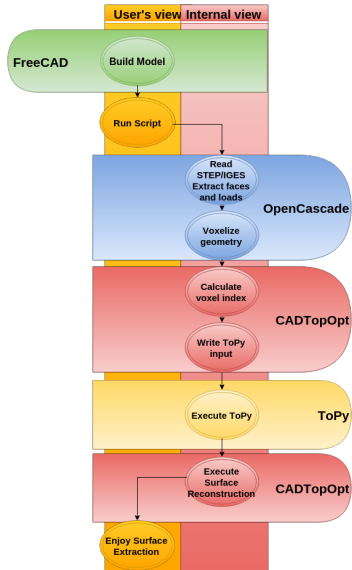
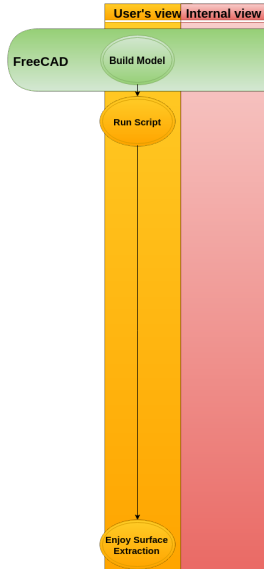


Figure: Surface extraction for Cantilever





But what does the user see?



But what does the
user see?
This!

The next steps MOVE TO LATER

- GUI for input
- Speed up ToPY
- Usage of different optimizers

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What is done?

- First part of the pipeline from CAD model to optimized voxel model:
 - ✓ CAD to STL with e.g. FreeCAD
 - ✓ STL to Voxels with CVMLCPP
 - ✓ Voxels to ToPy input with custom script
 - ✓ Topology optimized geometry with ToPy
 - ⌚ Surface reconstruction with VTKToolbox
- B-spline fitting
 - ✗ Automatic patch selection
 - ✗ Parametrization of obtained patches
 - ✓ B-spline fitting using least squares
 - ⌚ Smooth connection of patches
 - ✗ Conversion back to CAD

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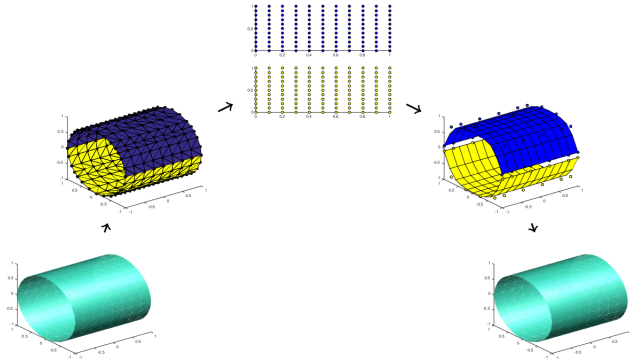
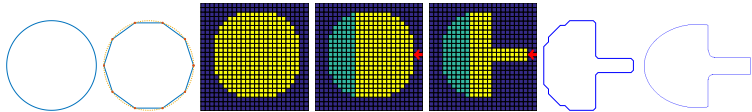
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What is next?

- Automation of the first part of the pipeline
- Integration of boundary conditions handling
- Implementation of remaining B-spline fitting steps (based on work of M.Eck & H.Hoppe)
- Further research on algorithms considering voxel geometry

Thank you for your attention!



Literature

- **William Hunter.** "Predominantly solid-void three-dimensional topology optimisation using open source software"
- **Gerrit Becker, Michael Schäfer, Antony Jameson.** "An advanced NURBS fitting procedure for post-processing of grid-based shape optimizations"
- **Matthias Eck, Hugues Hoppe.** "Automatic Reconstruction of B-Spline Surfaces of Arbitrary Topological Type"