Faculty of Architecture & the Built Environment

3D modelling of the built environment (GEO1004) — 5 ECTS

Location: CEG-Instruction Room 0.96
Date & time: 23 June 2025, 9:00
Responsible teacher: Ken Arroyo Ohori

1. The subject matter is in full accordance with the study guide.
2. This final exam is worth 45% of the final mark for the course.
3. The maximum grade for this course is 10.0. The minimum (unrounded) final mark to pass this course is 5.75, which will be rounded to 6.0. However, you need a weighted average of at least 50% in the combined exams ($0.1\times$midterm + $0.9\times$final) to be able to pass the course.
4. All questions have equal weight in this exam.
5. Answer directly on these pages. If there is not enough space, use the extra sheet at the end.
6. This is an open book/computer exam, so you are free to check the course materials (videos/handouts/assignments), both printed or on your computer, as well as any other materials you can find. However, you are **not allowed to communicate with others** and **the use of your phone is forbidden**.
7. This final exam has 12 questions, and 16 pages.
8. Fill out your name and student ID.
9. You have 2 hours to do this exam.

Name: ____________________

Student ID: ____________________

Lesson 1.2

Describe your own implementation of Homework 3 in terms of its handling of geometry, topology and semantics. There should be one statement about each of the three components (⅓ point each).

Lesson 2.1

How does a constrained triangulation or tetrahedralisation help you adequately represent objects with holes and cavities? **(a)** Explain it in your own words (½ point) and **(b)** illustrate it with an example (½ point).

Lesson 2.2

Assume you have LoD2.2 buildings stored in an OBJ file and all surfaces have been already triangulated. If you used the method prescribed to calculate the volume for Homework 2, discuss for each of the cases below what are the consequences for the calculation of the volume (¼ point each):

- one triangular face of the building is missing
- 2 triangles are wrongly oriented (their normals point inwards)
- the shape of the building has a genus of 1
- there are small gaps and overlaps between the triangles

Lesson 3.2

Using sparse encodings of voxels can be more or less efficient than the usual (dense) encoding. Using the typical features of a 3D city model (e.g. buildings, roads, water bodies and vegetation), describe an example where they would be much more efficient and one where they would be much less efficient (½ point each).

Lesson 4.1

When validating the geometry and topology of a solid (having one outer shell and several inner shells), we usually implement a hierarchical approach (starting from rings, to surfaces, to shells, and to solids). Explain in your own words why that is.

Lesson 4.2

During Homeworks 2 and 3, you read, modified, and wrote to disk several CityJSON files. Describe in detail two drawbacks of this format (¼ point each), which can be related to low-level issues, to the libraries used, etc. For each drawback, give a concrete example of how that negatively affected you during an assignment (¼ point each).

Lesson 5.1

Starting from an AHN4 point cloud of Delft, how could you use the MAT to extract the points on the surface of the faculty building? (½ point) Describe one significant drawback of this approach (½ point).

Lesson 5.2

Given a quadratic Bézier curve with point coordinates $(0, 0)$, $(10, 0)$, $(10, 10)$, what coordinates do we obtain when we evaluate it at $t = 0.5$? You should either write the calculation step by step or explain the reasoning you used to come up with the answer.

Lesson 6.1

Draw a CSG tree that produces a building with a non-2-manifold boundary. You may only use 3D boxes (cuboids) as primitives.

Lesson 6.2

Describe what is being represented in this IFC snippet. Provide as much information as you can obtain from it.

```
#1292829= IFCCARTESIANPOINT((-41680.,27360.,0.));
#1292831= IFCAXIS2PLACEMENT3D(#1292829,#19,#17);
#1292832= IFCLOCALPLACEMENT(#171,#1292831);
#1292833= IFCCARTESIANPOINT((1680.,0.));
#1292835= IFCPOLYLINE((#9,#1292833));
#1292837= IFCSHAPEREPRESENTATION(#100,'Axis','Curve2D',(#1292835));
#1292839= IFCCARTESIANPOINT((840.,0.));
#1292841= IFCAXIS2PLACEMENT2D(#1292839,#25);
#1292842= IFCRECTANGLEPROFILEDEF(.AREA.,$,#1292841,1680.,99.9999999999946);
#1292843= IFCAXIS2PLACEMENT3D(#6,$,$);
#1292844= IFCEXTRUDEDAREASOLID(#1292842,#1292843,#19,4050.);
#1292845= IFCCARTESIANPOINT((0.,4050.));
#1292847= IFCCARTESIANPOINT((-1680.,4050.));
#1292849= IFCCARTESIANPOINT((-1680.,0.));
#1292851= IFCPOLYLINE((#9,#1292845,#1292847,#1292849,#9));
#1292853= IFCCARTESIANPOINT((1680.,46.,-0.));
#1292855= IFCAXIS2PLACEMENT3D(#1292853,#17,#11);
#1292856= IFCPLANE(#1292855);
#1292857= IFCCARTESIANPOINT((1680.,46.,-0.));
#1292859= IFCAXIS2PLACEMENT3D(#1292857,#17,#11);
#1292860= IFCPOLYGONALBOUNDEDHALFSPACE(#1292856,.T.,#1292859,#1292851);
#1292861= IFCBOOLEANCLIPPINGRESULT(.DIFFERENCE.,#1292844,#1292860);
#1292862= IFCSTYLEDITEM(#1292844,(#40621),$);
#1292865= IFCSHAPEREPRESENTATION(#102,'Body','Clipping',(#1292861));
#1292867= IFCPRODUCTDEFINITIONSHAPE($,$,(#1292837,#1292865));
#1292869= IFCWALLSTANDARDCASE('2GlKNkI9906uY_feeouokH',#41,
                              'Basic Wall:22_Internal wall 100mm:6073404',$,
                              'Basic Wall:22_Internal wall 100mm:18167',
                              #1292832,#1292867,'6073404');
```

Lesson 7.1

As seen in Ravi's guest lecture, fusing two point clouds (e.g. AHN3 and AHN4) can both solve issues and create new ones. Describe an example of each of these (½ point each).

Lesson 7.2

Generalised maps do not have a predefined orientation. Explain concretely how this property could be useful to improve your implementation of Homework 1.

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