Faculty of Architecture & the Built Environment

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

Location: CEG-Instruction Room 1.98 (HG.1.98)
Date & time: 22 June 2026, 09:00
Responsible teacher: Ken Arroyo Ohori

1. The subject matter is in full accordance with the study guide.
2. This final exam is worth 50% 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 also need a minimum of 50% in this final exam 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 **static** materials you can find on the internet (e.g. technical books, documentation, articles). However, you are **not allowed to use LLMs** (such as ChatGPT, Gemini, Claude, or any other AI language model) during the exam. You are also **not allowed to communicate with others** and **the use of your phone is forbidden**.
7. This final exam has 10 questions, and 12 pages.
8. Fill out your name and student ID.
9. You have 2 hours to do this exam.

Name: ____________________

Student ID: ____________________

Lesson 1.1

(a) Describe the role of geometry, topology, and semantics in **one** of your homework assignments (½ point).

(b) For each component (geometry, topology and semantics), give a concrete example of how it was handled in your homework's code (½ point).

Lesson 1.2

In Homework 1, you used 3D convex hulls to simplify building blocks. In Homework 2, you computed volumes using signed tetrahedra. Explain how the boundary representation (brep) of a building relates to both operations. Specifically:

(a) how does the convex hull of a set of points relate to the brep of the resulting solid? (½ point)

(b) why does the signed tetrahedron volume method require a consistent orientation of the brep? (½ point)

Lesson 2.2

In Homework 2, you triangulated building surfaces using a constrained 2D triangulation.

(a) Explain why a constrained triangulation is needed rather than a simple unconstrained one (½ point).

(b) Describe a scenario where a 3D constrained Delaunay tetrahedralisation would be more appropriate than your 2D surface triangulation (½ point).

Lesson 3.1

In Homework 3, you voxelised a BIM model to extract rooms and the outer envelope.

(a) Explain why the connectivity used for the voxelisation targets and the connectivity used for flood-filling rooms must be chosen jointly. Hint: what would happen if you used 26-connectivity for targets and flood-filling? (½ point)

(b) In the context of digital twins for energy districts (Lesson 8.2), how could such a voxel model be used to estimate energy performance of individual rooms? (½ point)

Lesson 3.2

(a) Draw a CompositeSurface that is ISO19107 invalid because its individual surfaces would each be reported as invalid by val3dity (½ point).

(b) Draw a CompositeSurface with individually valid surfaces but which is still invalid as a whole (½ point).

Lesson 4.1

In a valid 2D generalised map of a building's surfaces, write the sequence of involutions you would apply to a starting dart to:

(a) visit all darts of the same surface (½ point), and

(b) visit all darts around a vertex (½ point).

Lesson 4.2

Give **two** concrete differences between CityGML and CityJSON that go beyond mere syntax, ie not just XML vs. JSON (¼ point each). For each, explain a possible consequence for the PLATEAU project (¼ point each).

Lesson 5.1

(a) Given a quadratic Bézier curve with control points $P_0 = (0, 0)$, $P1 = (2, 4)$, $P2 = (4, 0)$, compute the point at $t = 0.5$ using the de Casteljau algorithm, showing your steps (½ point).

(b) Explain how Bézier surfaces could represent a curved roof in a 3D city model. Would the surface be ISO19107-valid? (½ point)

Lesson 5.2

In Homework 3, you converted a BIM model to voxels. Suppose the BIM model contained only CSG trees with sphere primitives.

(a) Would it be easier or harder to voxelise the building compared to the OBJ approach you used? Explain (½ point).

(b) Give one type of geometry that is trivial in CSG but difficult to represent with voxels, and vice versa (½ point).

Lesson 6.2

Analyse this IFC snippet:

```
#1=IFCDIRECTION((0.,1.,0.));
#2=IFCDIRECTION((1.,0.,0.));
#3=IFCCARTESIANPOINT((0.,0.,0.));
#4=IFCAXIS2PLACEMENT3D(#3,#2,#1);
#5=IFCPLANE(#4);
#6=IFCCARTESIANPOINT((0.,0.,0.));
#7=IFCAXIS2PLACEMENT3D(#6,$,$);
#8=IFCCARTESIANPOINT((0.,0.));
#9=IFCCARTESIANPOINT((6000.,0.));
#10=IFCCARTESIANPOINT((6000.,3000.));
#11=IFCCARTESIANPOINT((0.,3000.));
#12=IFCPOLYLINE((#8,#9,#10,#11,#8));
#13=IFCPOLYGONALBOUNDEDHALFSPACE(#5,.T.,#7,#12);
```

(a) Briefly describe the geometry represented here (½ point).

(b) Explain why it cannot be directly represented as a Solid (½ point).

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