Faculty of the Built Environment & Architecture

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

Location: Pulse Hall 10
Date & time: 14 April 2022, 09:00–11:00
Responsible teacher: Ken Arroyo Ohori

1. The subject matter is in full accordance with the study guide.
2. This final exam is worth 35% 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 (midterm + this one) 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 extra sheets and staple them at the end.
6. This is an open-book exam, only paper is allowed. No computer/phone/etc; a calculator is fine.
7. This final exam has 12 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

Using examples from your homework assignments, write three sentences that relate the processing you did for an assignment to each of the following: (a) its geometry (⅓ point), (b) its topology and (⅓ point) (c) its semantics (⅓ point).

Lesson 1.2

Draw an example of a polygon with a hole and a non-1-manifold boundary (½ point). Explain why it is non-manifold (½ point).

Lesson 2.1

In a 2D generalised map:

(a) What is the sequence of involutions that is necessary to obtain all the darts around a vertex in clockwise order? (½ point)

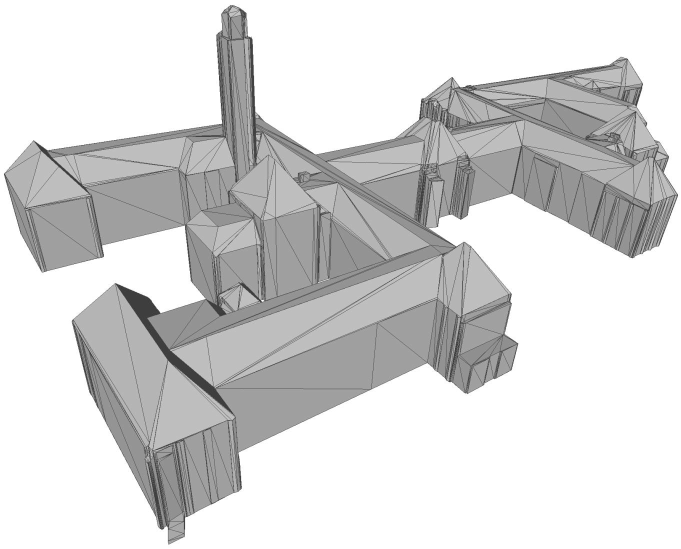
(b) Draw an example map to demostrate it. (½ point)

Lesson 2.2

Explain in your own words why we cannot use 1-dimensional targets to voxelise lines in 3D space. Hint: think of counterexamples.

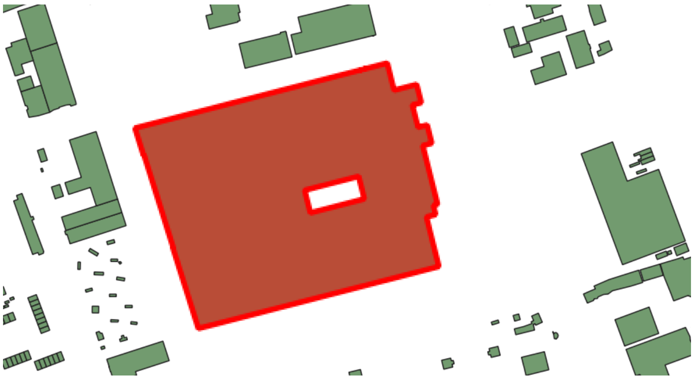
Lesson 3.1

You obtained an .obj file of BK-City (as shown below) and you want to construct its Constrained Delaunay tetrahedralisation (ConsDT) (eg with the software TetGen). (1) Is it always possible to do so? What properties should the Solid have? (2) Assume you succeeded, explain how you would use the output of the ConsDT procedure to calculate the volume of BK-City.



Lesson 3.2

You have the building footprint below (in red, it is from the BAG), and you extrude it to create a LoD1.2 model (at height 15m). Characterise the 3D shape you obtain, using the ISO19107-terminology. What geometry type will you use to store it in CityJSON? How many surfaces? Their orientation? Is it valid?



Lesson 4.1

Imagine you're doing an internship at the City of Berlin, where they have a LoD2.2 model of all their buildings (but no other LoDs). Your boss asks you to give her a LoD1.2 model of all the buildings in an area. (1) Describe in details a methodology to perform this (assume the input is a CityJSON file); (2) Why did your boss ask you this? Give 2 reasons why having a LoD1.2 is "better" than a LoD2.2 one.

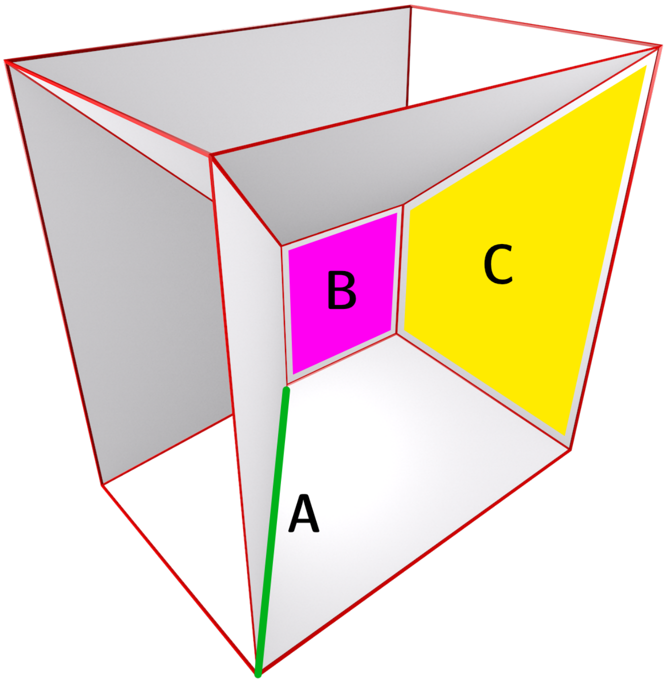
Lesson 4.2

Given a quadratic Bézier curve with point coordinates $(0,0)$, $(1,2)$, $(2,0)$, what coordinates do we obtain when we evaluate it at $t = 0.5$? (½ point) Explain your reasoning (½ point).

Lesson 5.1

Below you see the medial axis of a 3D box (Fig. 7.2c of the book). There are 3 highlighted parts: A, B and C. All the medial atoms in the same part have the same configuration of spoke vectors (ie. same number and orientation).

1) What is the number and orientation of spoke vectors for each part? and 2) how does the medial radius vary throughout each part?



Lesson 5.2

The building reconstruction method explained in Section 12.3 of the book derives a 3D mesh by extrusion from a 2D roof partition. Does this extrusion process always produce a 2-manifold 3D mesh in theory? If yes, explain why. If no, give a counter example.

Assume that 1) we start with a valid roof partition (ie. a planar partition of the building footprint with a non-vertical 3D plane assigned to each part) and 2) the floor face lies under all the roof faces in the final model.

Lesson 6.1

There are three circles centred at $(0,0)$, where circle $\mathbb{A}$ has a radius of 3, circle $\mathbb{B}$ has a radius of 2 and circle $\mathbb{C}$ has a radius of 1. For the Boolean point set operation $\mathbb{D} = \neg((\mathbb{A} - \mathbb{B}) \cup \mathbb{C})$, draw a tree showing the individual CSG operations you need to perform (½ point) and the final result (½ point).

Lesson 6.2

Imagine that we want to do the reverse conversion of Homework 3 (Geo to BIM). Describe the outline of a method with the main steps to perform this conversion.

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