Master in High Performance Computing

Continuum mechanics and fluid-structure interaction problems: mathematical modelling and numerical approximation

deal.II LAB — the Triangulation class

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Aims for this week

- Gain familiarity with three core classes
  - **Triangulation**
  - **DoFHandler**
  - **FiniteElement**
- Create and interrogate meshes
- Create and interrogate sparsity patterns

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Reference material

- Main page
  https://dealii.org/current/doxygen/deal.II/index.html
- Tutorials
  - Step-1
    https://dealii.org/current/doxygen/deal.II/step_1.html
  - Step-49
    https://dealii.org/current/doxygen/deal.II/step_49.html
  - Step-2
    https://dealii.org/current/doxygen/deal.II/step_2.html

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First and **BIGGEST** tip

- Program **defensively**
  - Program and test in **debug** mode
    - Additional compiler warnings
    - Add assertions
  - Create papers' results in **release** mode

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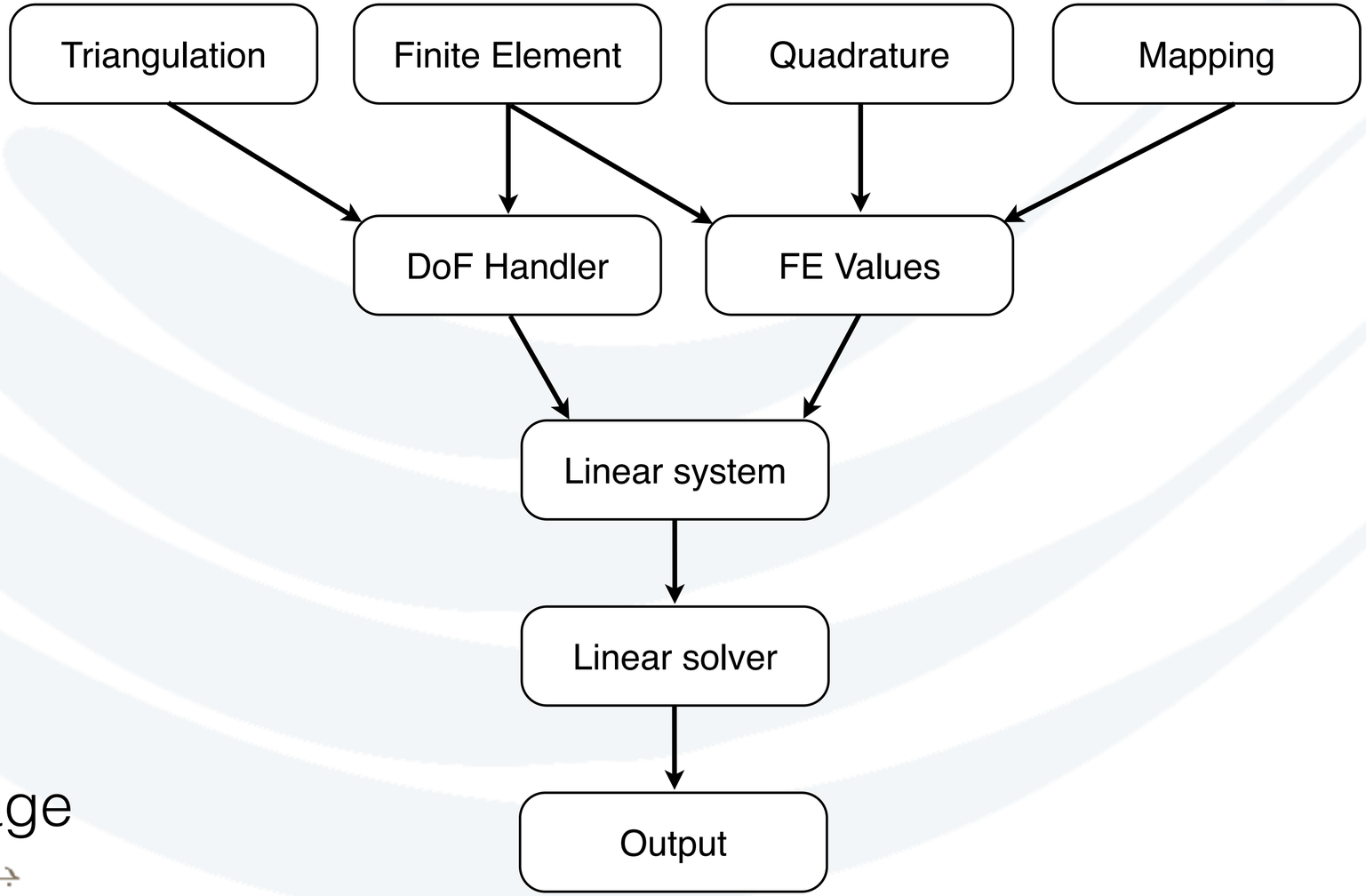
Structure of a prototypical FE problem



Main page

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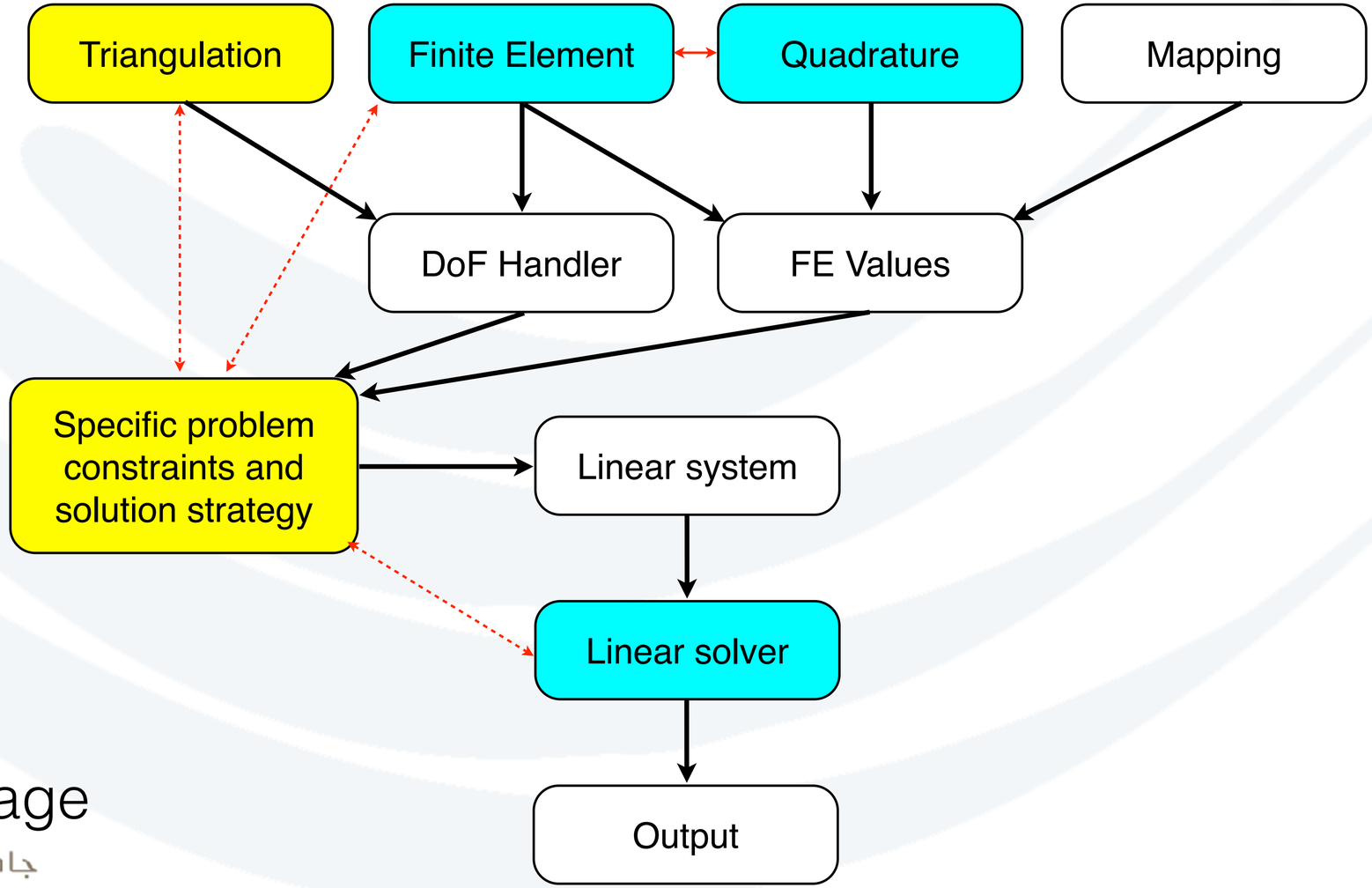
Structure of a prototypical FE problem



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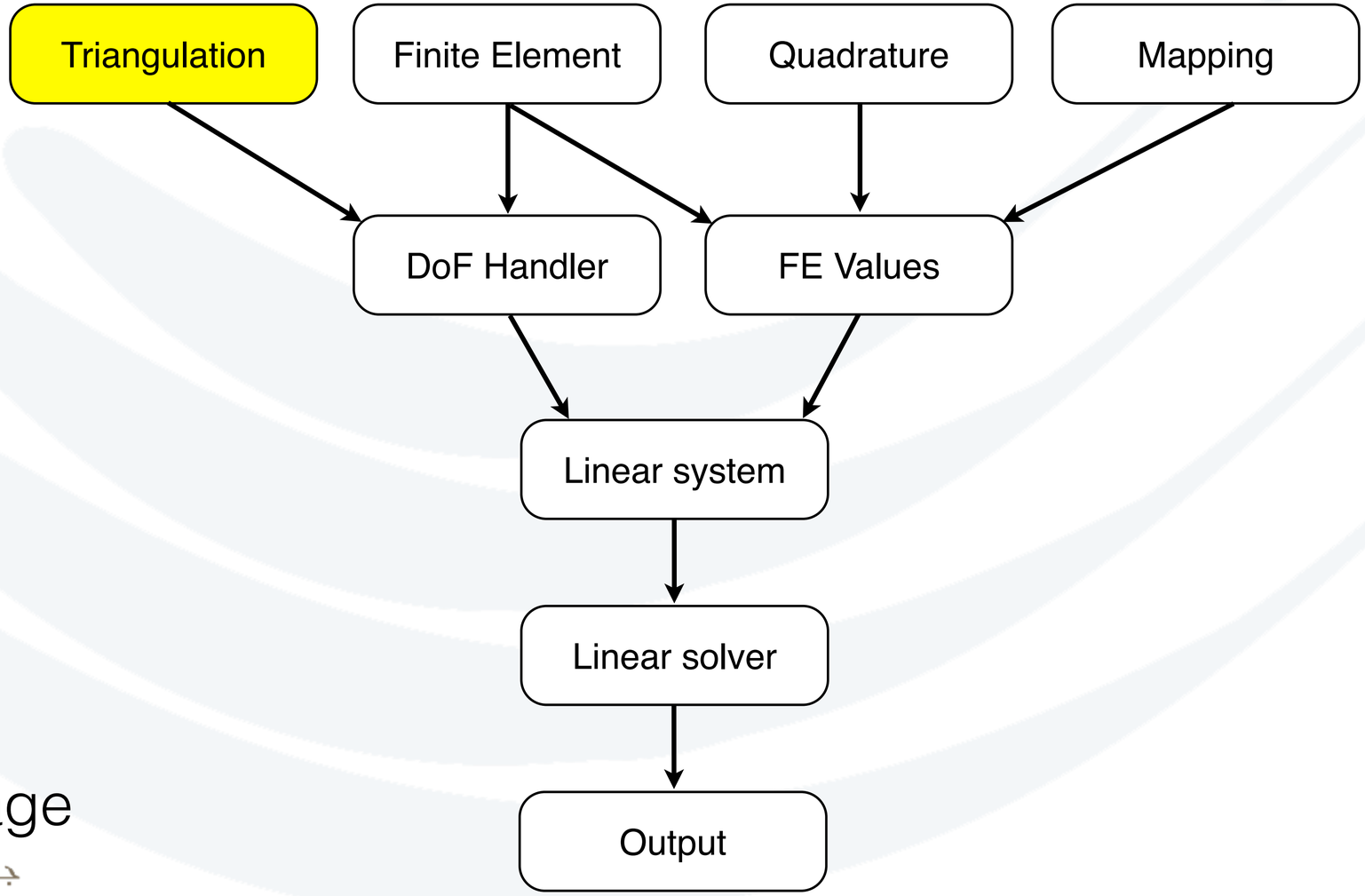
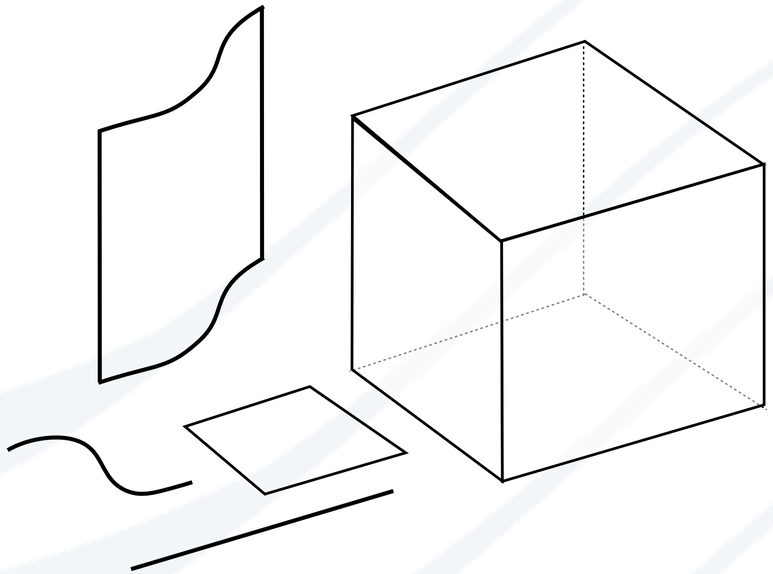


Main page

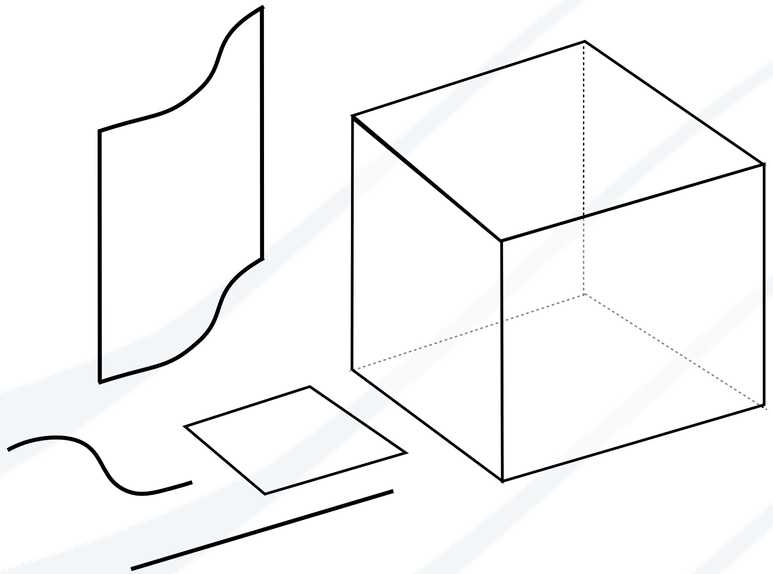
https://dealii.org/current/doxygen/deal.II/index.html

Interaction with geometry: the Triangulation class

- Describes problem geometry
  - Support for lines, quad, hex elements
  - Conceptually even higher order!
  - Structured/unstructured meshes
  - Co-dimension 1 or 2 case
- Grid creation
  - Built-in basic grid generation and manipulation tools
  - Can read in grids



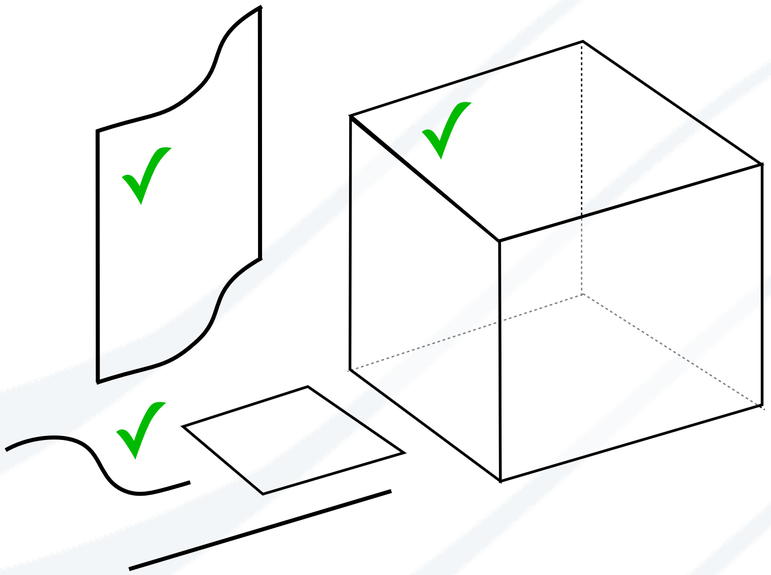
Interaction with geometry: the Triangulation class

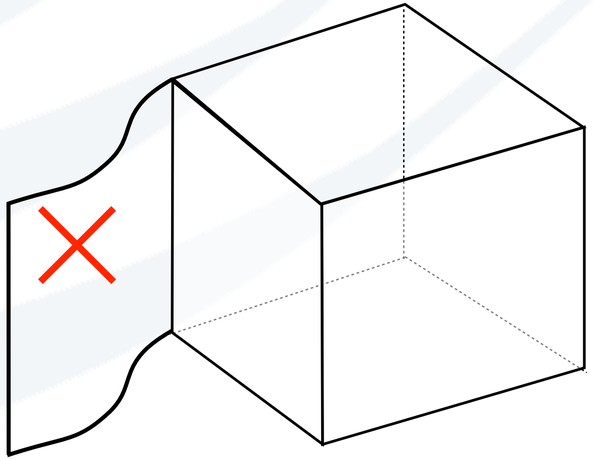


- Assign helper ID's
  - Materials
  - Boundaries
  - Manifolds
- Allows storage of custom data-structure attached to each cell/face
- Cells know about neighbour cells
  - Useful for DG methods

Interaction with geometry: the Triangulation class

- Can enforce topologies
  - Manifolds on boundary
  - Internal manifolds
- Disadvantage
  - Cannot mix triangulation types
  - e.g. Volumetric body with extended manifold surface

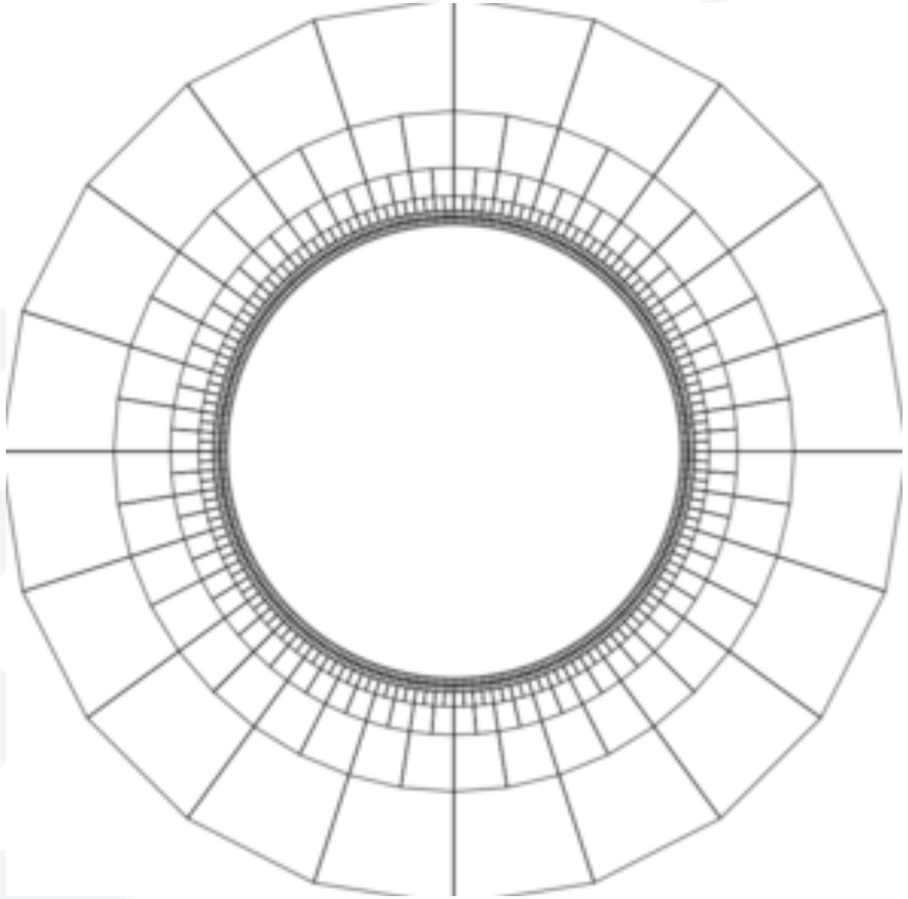




Interaction with geometry: the Triangulation class

- Demonstration: Step-1, step-49
  https://www.dealii.org/current/doxygen/deal.II/step_1.html
  https://www.dealii.org/current/doxygen/deal.II/step_49.html
  http://www.math.colostate.edu/~bangerth/videos.676.5.html
  http://www.math.colostate.edu/~bangerth/videos.676.6.html

- Key points
  - deal.II headers
  - Creating a triangulation
  - Boundary topology
  - Traversing a triangulation
  - Querying geometric information
  - Manipulating a triangulation
  - Aspects of grid refinement
  - Visualising a triangulation



Triangulation

$$\mathcal{T}_h := \cup_{m=0}^{\text{n\_active\_cells}} \{K_m\}$$

- Mesh/**Triangulation**/Grid: a collection of **cells, faces,** and **vertices**
- if the mesh has been refined (possibly in an adaptive way):
  - hierarchy of refinement levels
- **Triangulation** in deal.II only stores the geometry
- Main Reference: https://www.dealii.org/current/doxygen/deal.II/group__grid.html

Iterators and Accessors

$$\mathcal{T}_h := \cup_{m=0}^{\text{n\_active\_cells}} \{K_m\}$$

- An **iterator** in **C++** is an object that enables programmers to traverse a container,
- deal.II gives access to cells via **iterators:** they are pointers to objects that give you **access** to information
  - increment operation: `operator ++`
  - decremented operation: `operator--`
  - **`begin()`**/**`begin_*()`**: first element of a collection
  - **`end()`**: one-past-the-end iterator
  - **access** operator: the **->** command, i.e., **cell->center()**

Iterators and Accessors

$$\mathcal{T}_h := \cup_{m=0}^{\text{n\_active\_cells}} \{K_m\}$$

- An **accessor** in **C++** is an object that *hides* the internal details of a (possibly complex, hierarchical, distributed, etc.) container class, and gives you *access* to *information*

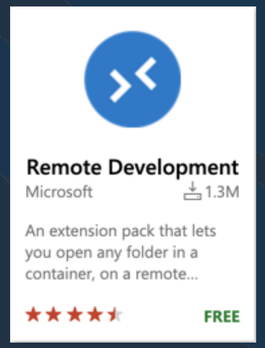
- deal.II **iterators** acts as pointers to **accessors:**

  - Accessors in deal.II: **lines, quads, tria, hexes, tetra, etc.**

  - `Ref:` https://www.dealii.org/developer/doxygen/deal.II/group__Iterators.html

Setting up VSCode

- Download and install **Docker**: https://www.docker.com/products/docker-desktop
  - Read some doc: https://www.docker.com/get-started
- Download and install: https://code.visualstudio.com/download
  - Read some doc: https://code.visualstudio.com/docs
  - Install the following extension:



Open the course repository

- Clone the repository of the course to a directory of your liking
- Open the directory containing the repository with Visual Studio Code (the directory contains a hidden folder, called “.**devcontainer”,** used by VSCode to understand the
- VSCode should ask you if you want to reopen the folder within a container. Say yes.
- VSCode will now download a docker image. The first time around, this will take some time.