SiF2020: OpenSEES Workshop

Session 1: Getting started and nonlinear analysis in OpenSEES

Mhd Anwar Orabi

A little about me

- Call me Anwar
- BSc in Civil Engineering, MSc (DIC) in Structural Engineering
- A PhD candidate at the Hong Kong Polytechnic University
- Using OpenSees for my research
- Interested in behaviour of thin metallic shells, finite element analysis, and global behaviour of structures in fire
- You can follow me on GitHub
- Or email me at anwar.orabi@connect.polyu.hk

The workshop

Getting started and nonlinear analysis in OpenSees	Mhd Anwar Orabi
Using GiD for OpenSees and 3D thermo-mechanical analysis	Mhd Anwar Orabi
Short Break	
Heat transfer and Fire models in OpenSees, and coupling FDS and OpenSees	Aatif Alikhan and Mustesin Khan
Short Break	
DIY: Add your own code	Liming Jiang

This session

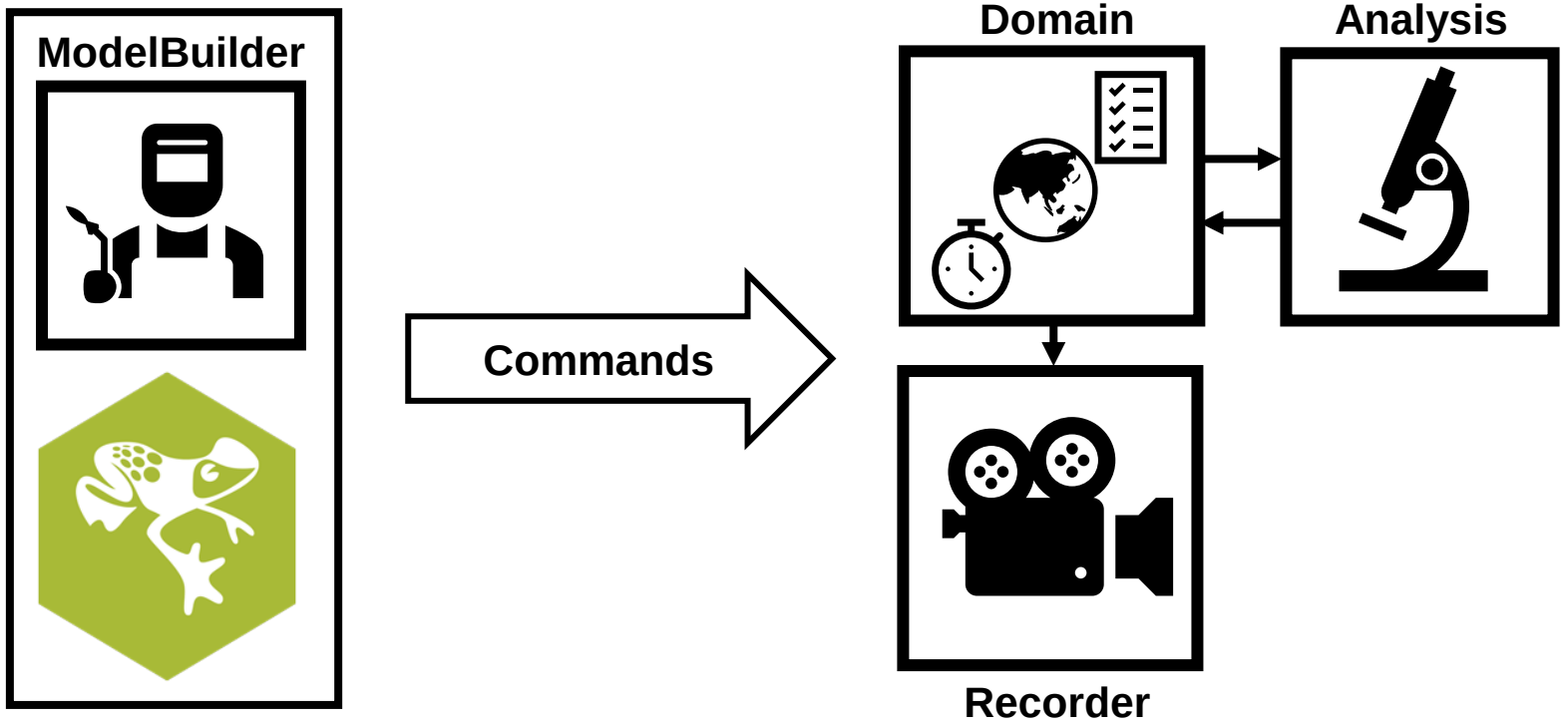
- What is OpenSEES and how does it generally work?
- How to set up OpenSEES on your computer?
- How to write code that the OpenSEES interpreter understands?
- Can we solve a nonlinear problem in OpenSEES now?

What is OpenSEES?

- **Open S**ystem for **E**arthquake **E**ngineering **S**imulation
- Open source – free for non-commercial use
- Developed by Frank McKenna and Gregory Fenves at UC Berkley
- Extended for Fire by the team of Asif Usmani then at Edinburgh, and now at the Hong Kong Polytechnic University
- For more details, see here.

How does OpenSEES work?

- Written in C++, but interfaced with a language called Tcl
- There is a Python-interfaced version
- Object oriented approach to the Finite Element Problem



Let's get started!

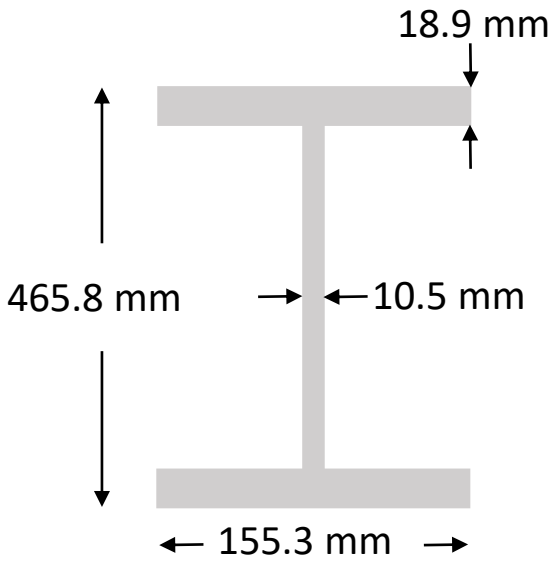
- Download Tcl/Tk
- Download OpenSEES (for Fire)
- Download NotePad++ (optional)

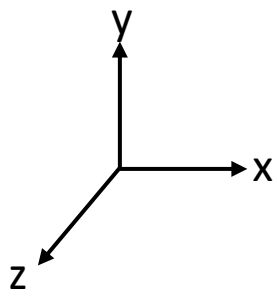
Tcl basics

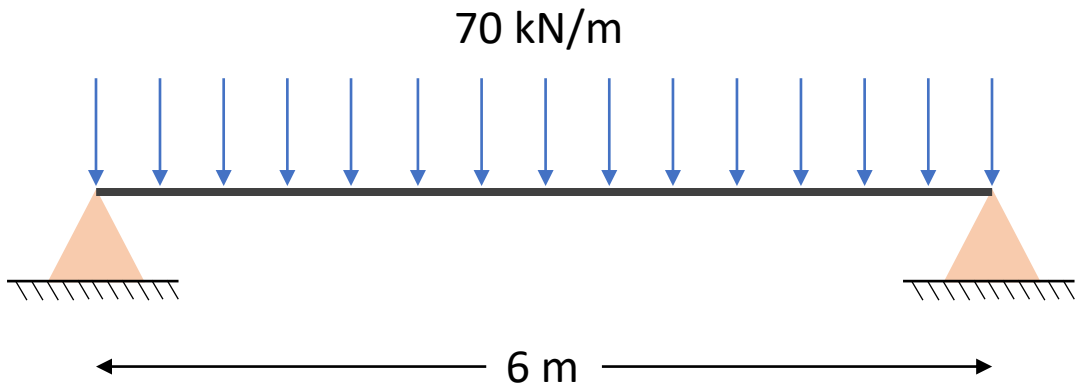
- General syntax
- Setting a variable
- Getting a variable's value
- Mathematical expressions
- Conditionals
- Loops
- Take a look here when you're lost

Let's try an exercise

- Axially restrained beam subjected to uniform load and then to uniform heating up to 900 °C
- UKB 457×191×98 with f_y = 275 MPa





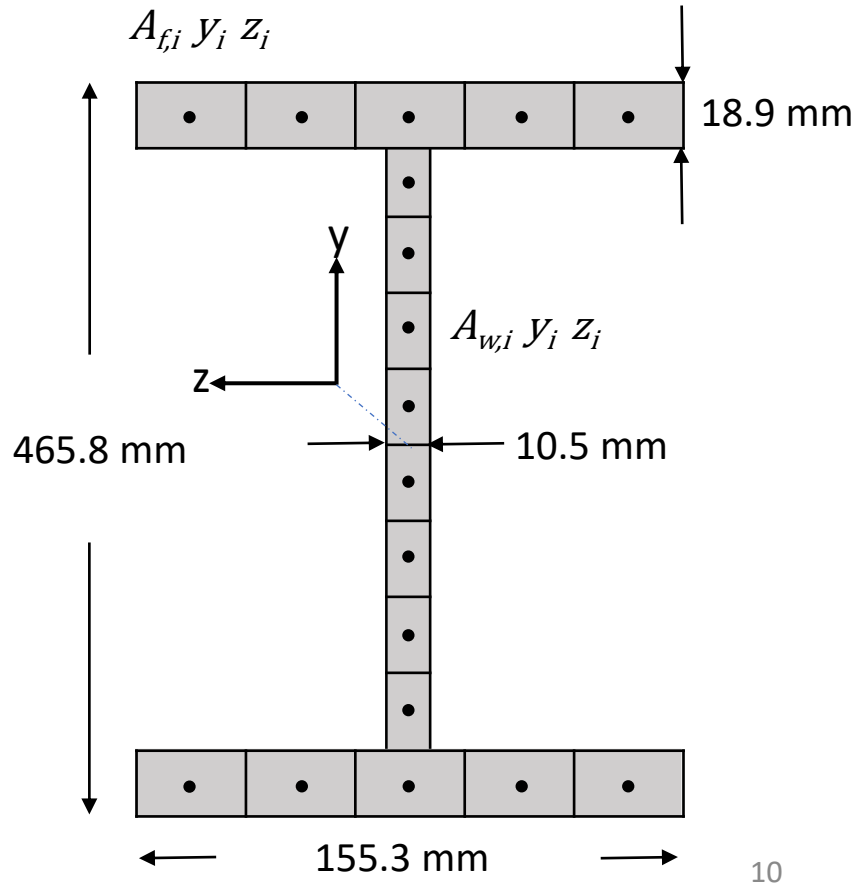


Section discretisation

- To consider material nonlinearity, we will discretise our section into fibers

$$A_{f,i} = \frac{b_f \times t_f}{5} = \frac{155.3 \times 18.9}{5} = 587\ mm^2 = 0.000587\ m^2$$

$$A_{w,i} = \frac{h_w \times t_w}{8} = \frac{(465.8 - 18.9 \times 2) \times 10.5}{8} = 561.75\ mm^2 = 0.00056175\ m^2$$



What is the workflow?

I. Building the model

1. Define the domain's dimensionality: 2D vs. 3D
2. Define the nodes and establish their boundary conditions and/or nodal masses
3. Define the elements and establish their type, sections, and the relationship between local and global coordinates
4. Define the load pattern and apply to the desired nodes and/or elements
5. Define the recorder object and what it will record

What is the workflow?

II. Creating the analysis object by defining:

1. Constraints: how DOF relate to one another (compatibility)
2. Numberer: maps the nodes and their respective equations
3. System: solver and storer of the equation system
4. Test: tests for convergence during a solution algorithm
5. Algorithm: specify which solution algorithm to use for tracing the equilibrium path
6. Integrator: does the numerical work at each iteration in order to move to the next step
7. Analysis: uses all previous objects to create the analysis object

Where to get information about the commands used?

- The OpenSEES command manual
- The OpenSEES for Fire command manual
- The examples posted on our page

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Session 2: Using GiD for OpenSEES and 3D thermo-mechanical analysis

Mhd Anwar Orabi

This session

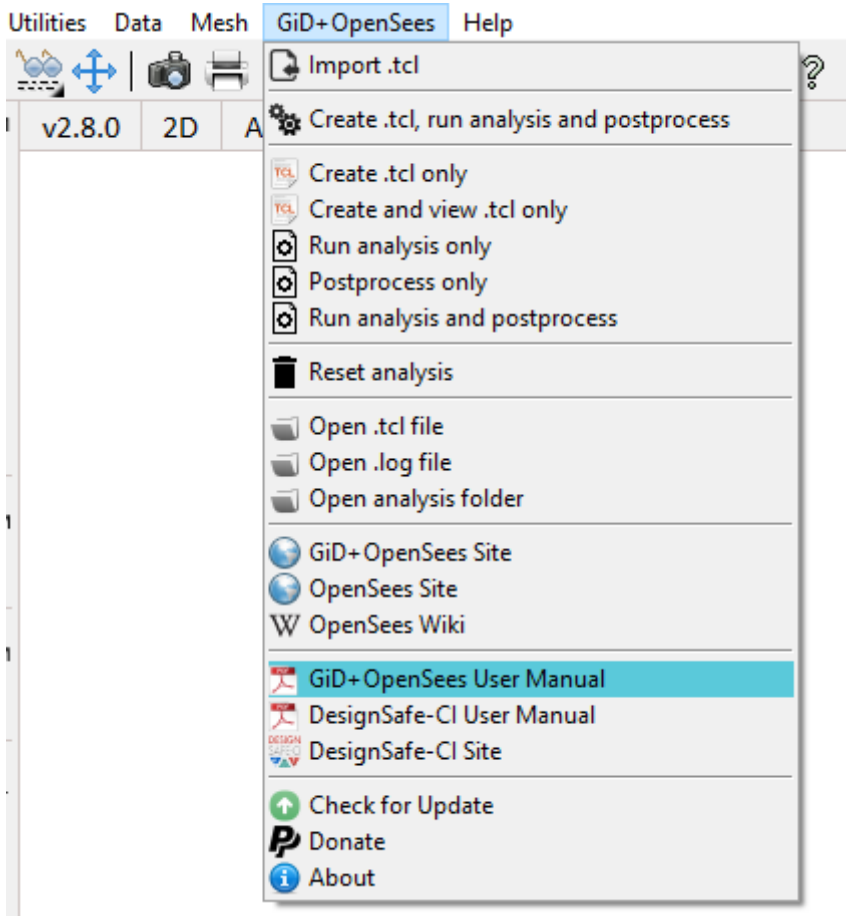
- What is GiD and how to set it up?
- How to building an OpenSEES model using GiD?
- What should the user look out for when using GiD?

What is GiD?

- “GiD is a universal, adaptive and user-friendly pre and post processor for numerical simulations in science and engineering.”
- Free for up to 5000 nodes (and some additional limitations).
- Basically, a graphical interface we can use for OpenSees.
- Let’s start setting it up:
- GiD
- GiD+OpenSees Interface 2.8.0
- OpenSees for Fire Interface

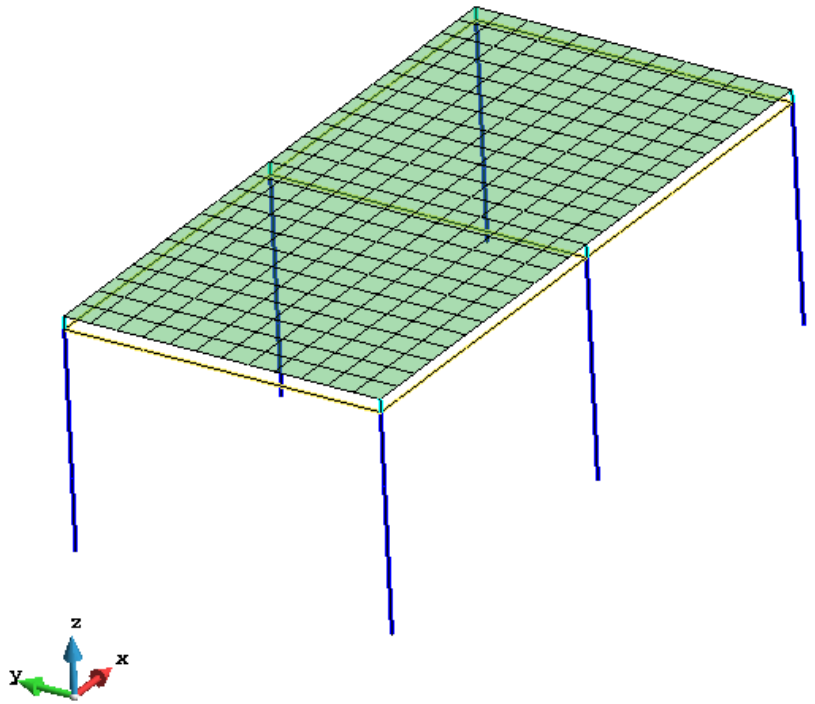
Is there any documentation?

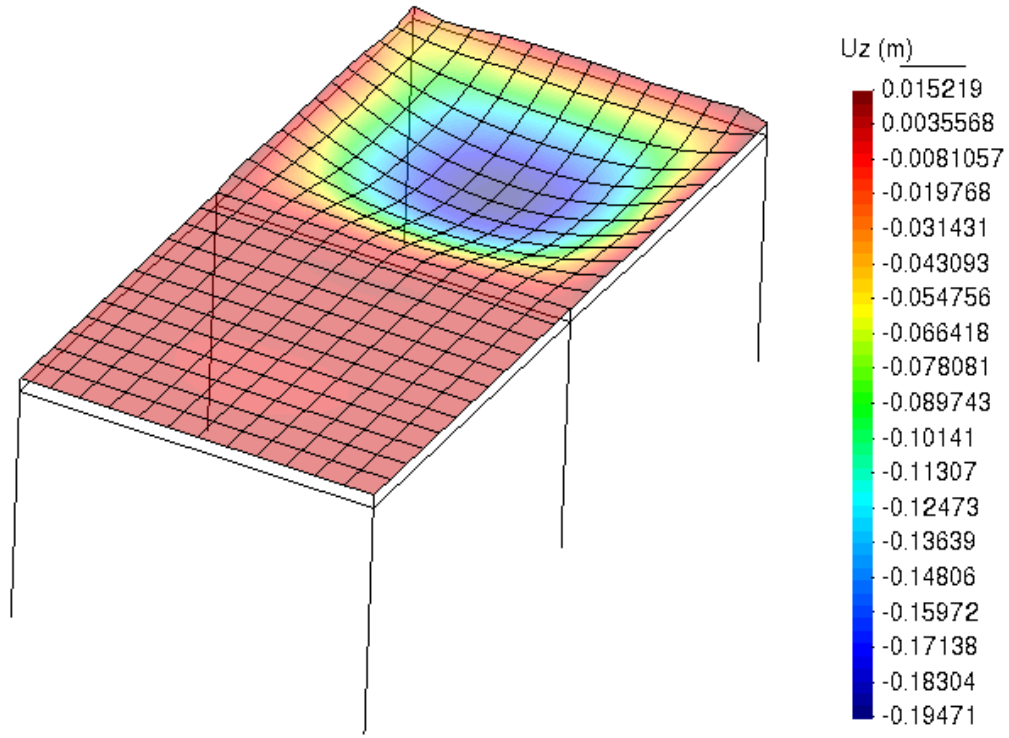
- GiD has an extensive set of documentation found here.
- You got the extensive set of documentation that Aristotle University of Thessaloniki wrote for the original interface with your download.
- As you will see in this workshop, this is all you need.



Let’s jump right in!

- Two-bay steel frame + concrete floor.
- Linear gradient with 800 °C bottom and 100 °C top.





Follow this checklist:

- Define units
- Define geometry
- Check and refresh model dimensions to 3D
- Define materials
- Define sections
- Define elements
- Assign elements
- Assign boundary conditions
- Set analysis interval
- Assign loads
- Assign mesh controls
- Mesh
- Check connectivity
- Check outputs
- Create Tcl file
- Check Tcl file for compliance with your model
- Run analysis