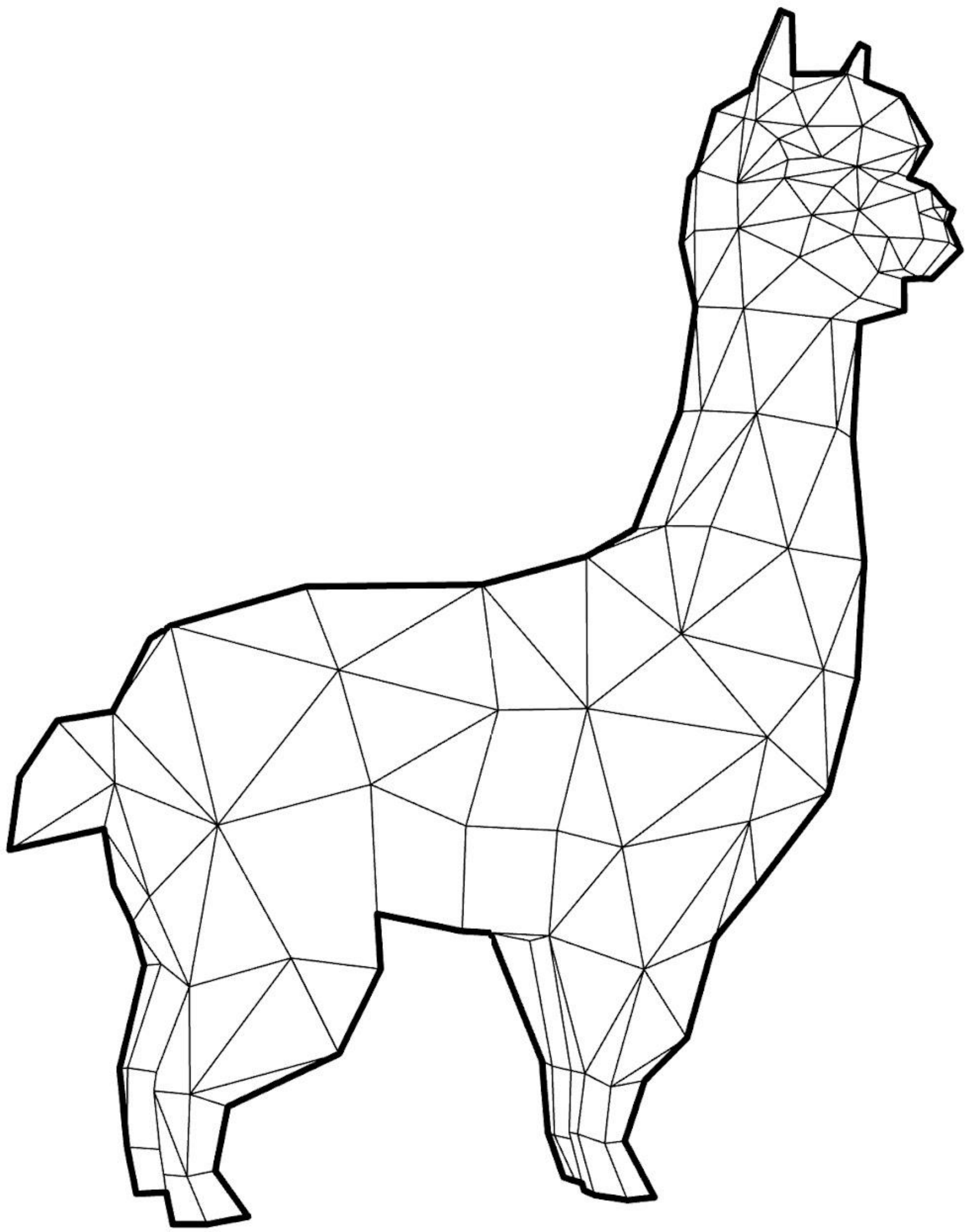
Alpaca4d



A revolutionary Parametric FEA software

Introduction

Alpaca4d is a Grasshopper plugin which has been developed on top of **OpenSees**.

The library is mostly used by researchers and academia because of the not user-friendly behaviour even if the math behind the library is highly sophisticated.

The main idea of **Alpaca4d** is to provide an efficient and easy way to use OpenSees without writing any line of code.

The belief is to bring more users to perform structural analyses with Opensees in a parametric environment such as Grasshopper.

Introduction

https://opensees.berkeley.edu

i.e. Catenary Cable

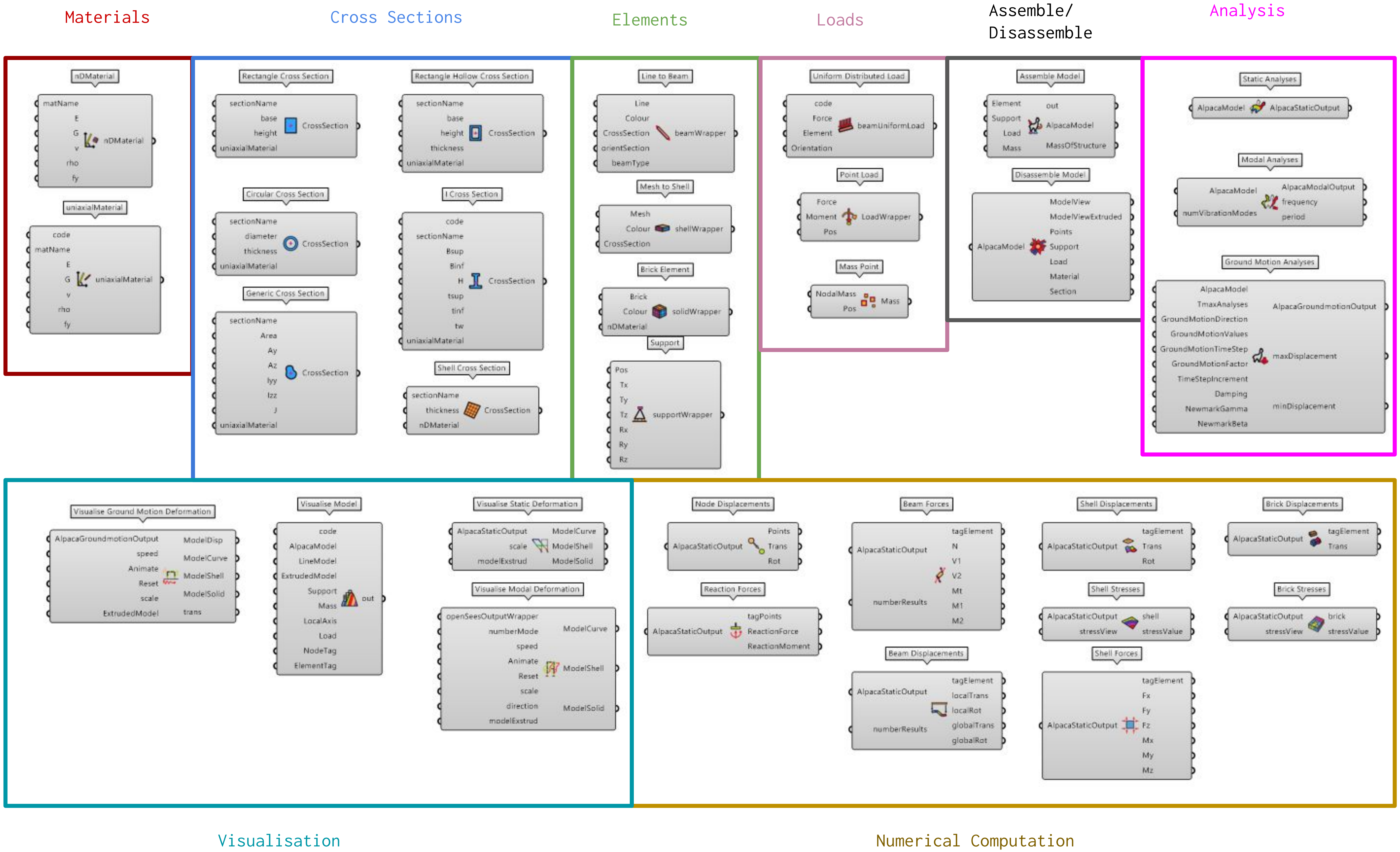
Command_Manual

This command is used to construct a catenary cable element object.

element CatenaryCable $tag $iNode $jNode $weight $E $A $L0 $alpha $temperature_change $rho $errorTol $Nsubsteps $massType

$eleTag	unique element object tag
$iNode $jNode	end nodes (3 dof per node)
$E	elastic modulus of the cable material
$A	cross-sectional area of element
$L0	unstretched length of the cable
$alpha	coefficient of thermal expansion
$temperature_change	temperature change for the element
$rho	mass per unit length
$errortol	allowed tolerance for within-element equilbrium (Newton-Rhapson iterations)
$Nsubsteps	number of within-element substeps into which equilibrium iterations are subdivided (not number of steps to convergence)
$massType	Mass matrix model to use (**$massType = 0** lumped mass matrix, **$massType = 1** rigid-body mass matrix (in development))

Plug-in

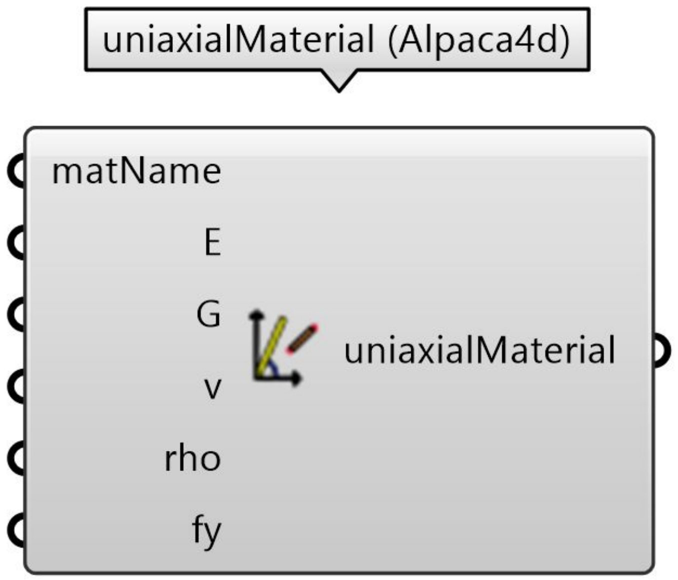


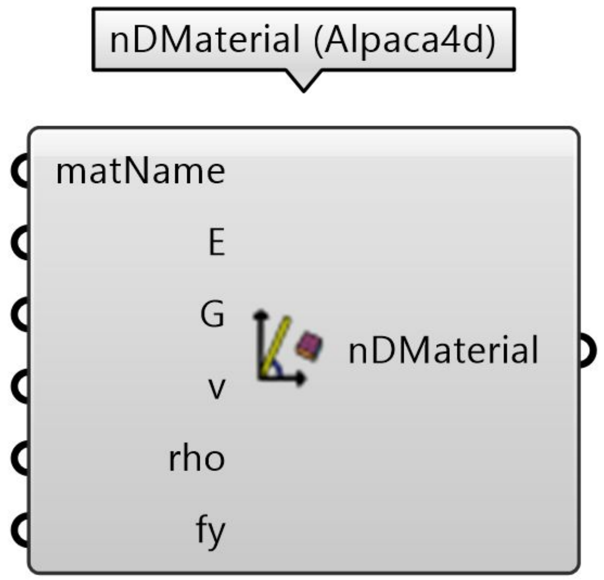
Materials
Cross Sections
Elements
Loads
Assemble/
Disassemble
Analysis
nDMaterial
uniaxialMaterial
Rectangle Cross Section
Rectangle Hollow Cross Section
Circular Cross Section
I Cross Section
Generic Cross Section
Shell Cross Section
Line to Beam
Mesh to Shell
Brick Element
Support
Uniform Distributed Load
Point Load
Mass Point
Assemble Model
Disassemble Model
Static Analyses
Modal Analyses
Ground Motion Analyses
Visualise Ground Motion Deformation
Visualise Model
Visualise Static Deformation
Visualise Modal Deformation
Node Displacements
Reaction Forces
Beam Forces
Beam Displacements
Shell Displacements
Shell Stresses
Shell Forces
Brick Displacements
Brick Stresses
Visualisation
Numerical Computation

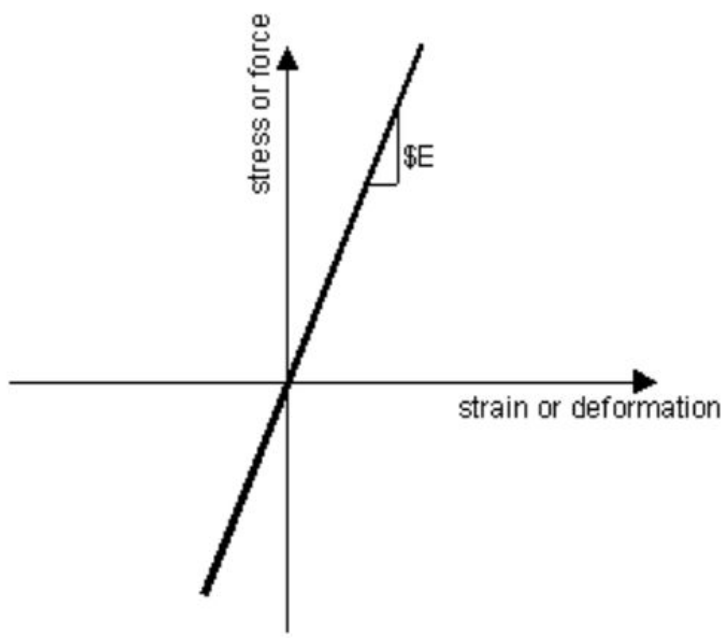
Materials

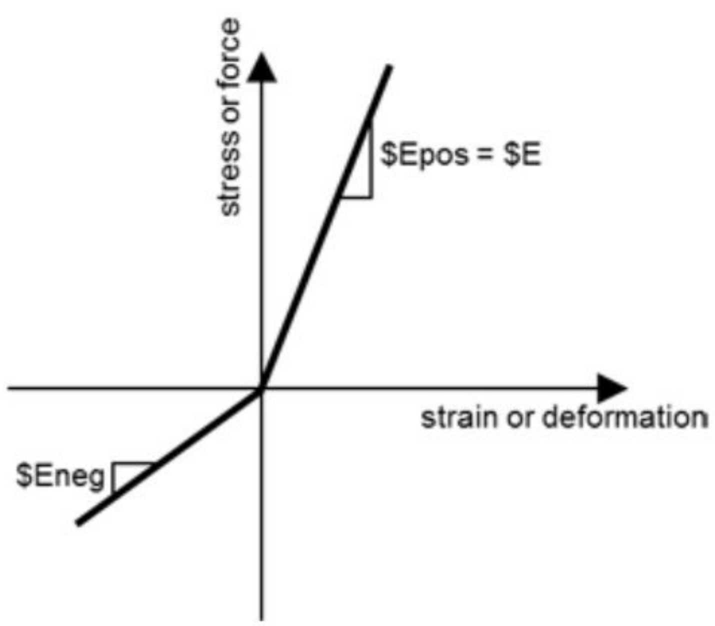
UniaxialMaterial is used to construct a material object which represents uniaxial stress-strain relationships. The implemented relationship is Linear Elastic.

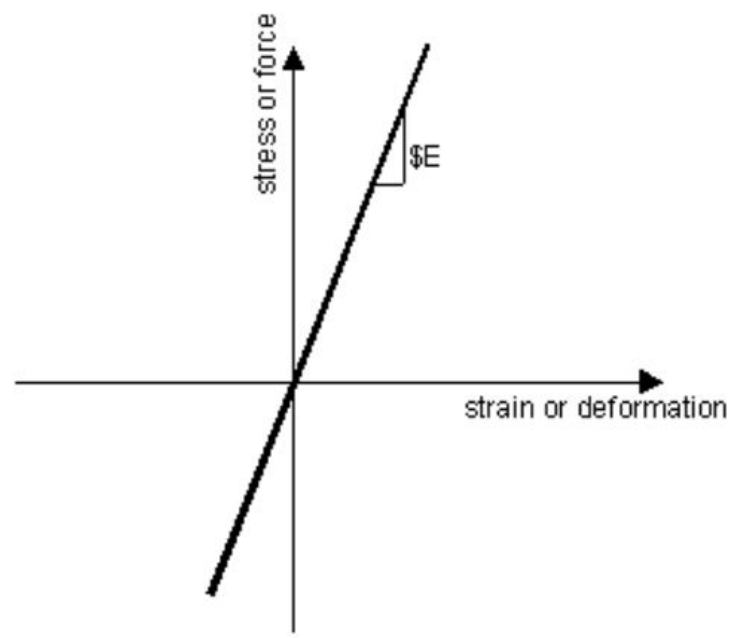
NDMaterial is used to construct a material object which represents the stress-strain relationship at the gauss-point of a continuum element. The behaviour is an Elastic Isotropic.







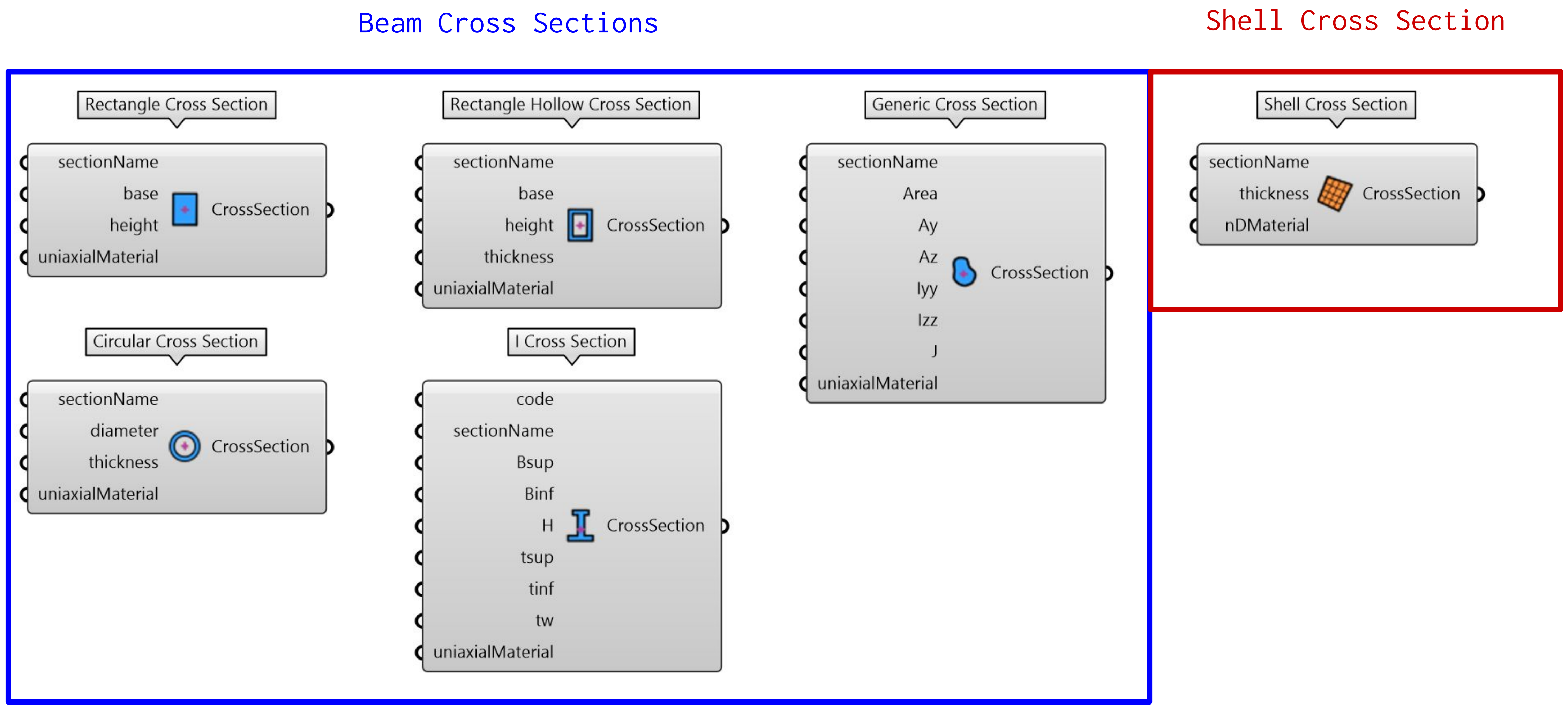




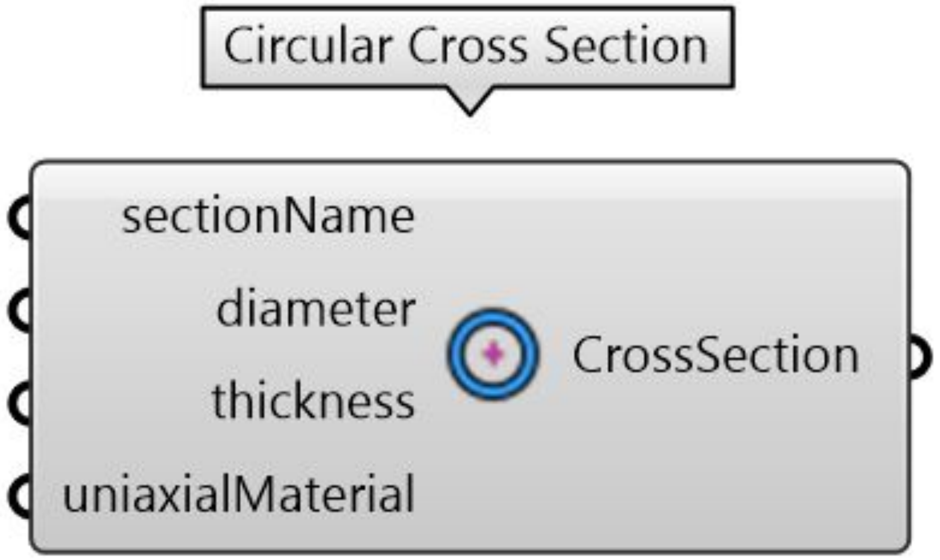
Cross Sections

Solid rectangle section, Circular Hollow Section, Rectangular Hollow Section, I-Section and Generic Cross Section are provided to the users to assign mechanical properties to a beam element.

Constant thickness section has been implemented for shell elements.



Cross Sections




```python
import math
import Grasshopper as gh

def CircleCrossSection(sectionName, diameter, thickness, uniaxialMaterial):
    sectionName = sectionName
    shape = "circular"
    diameter = diameter / 1000          # Input value in mm --> Output m
    thickness = thickness / 1000        # Input value in mm --> Output m
    if thickness == 0 or thickness == diameter / 2:
        Area = math.pow(diameter,2)/4  * math.pi
        Ay = Area * 0.9
        Az = Area * 0.9
        Iyy = math.pow(diameter,4)/64 * math.pi
        Izz = Iyy
        J = pow(diameter,4)/32 * math.pi
    elif thickness < diameter/2 and thickness >= 0:
        Area = (math.pow(diameter,2)-math.pow((diameter-2*thickness),2))/4 * math.pi
        Ay = Area * 0.9
        Az = Area * 0.9
        Iyy = (math.pow(diameter,4)-math.pow((diameter-2*thickness),4))/64 * math.pi
        Izz = Iyy
        J = (math.pow(diameter,4)-math.pow((diameter-2*thickness),4))/32 * math.pi
    else:
        msg = "Incorrect values. Thickness has to be greater than D/2 and greater than 0"
        ghenv.Component.AddRuntimeMessage(gh.Kernel.GH_RuntimeMessageLevel.Error, msg)

    material = uniaxialMaterial

    return [[ Area, Ay, Az, Iyy, Izz, J, material, [shape, diameter, thickness], sectionName ]]
```

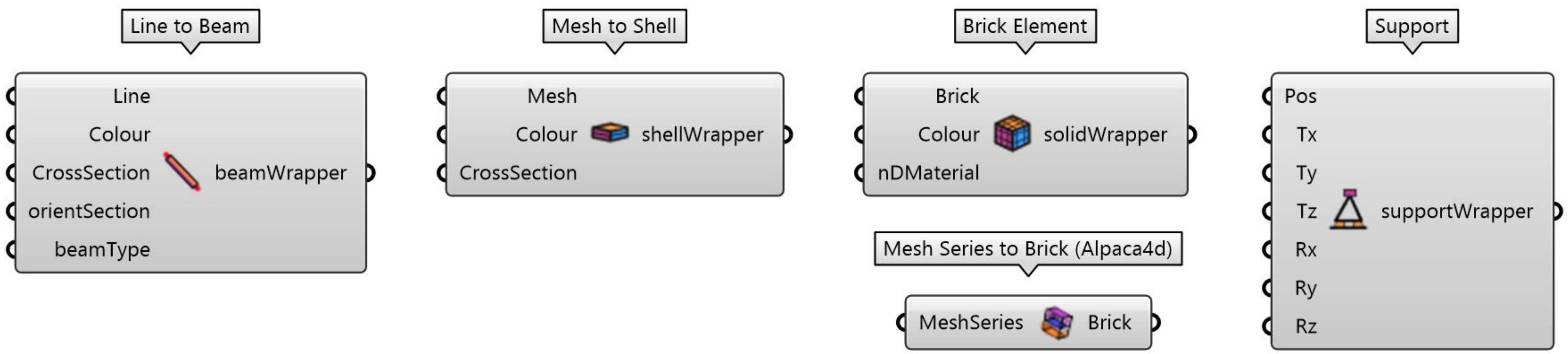
Elements

The finite elements implemented are **Elastic Timoshenko Beam Column Element, ShellMITC4-ShellDKGT, bbarBrick.**

Line to Beam component converts a line geometry to a *Timoshenko* Beam.

Mesh to Shell component converts a mesh geometry to a **Shell Element.** Shell elements are used to model structures in which one dimension, the thickness, is significantly smaller than the other dimensions. Triangular faces will be converted to a **ShellDKGT** formulation and the Quad faces to a **ShellMITC4** formulation.

Brick Element component converts an hexahedral element into a **bbarBrick.** A hexahedron is any polyhedron with six faces. It is generally a difficult task to convert a generic solid into a set of hexahedron and **MeshSeriesToBrick** component might help to construct some simple polyhedron.



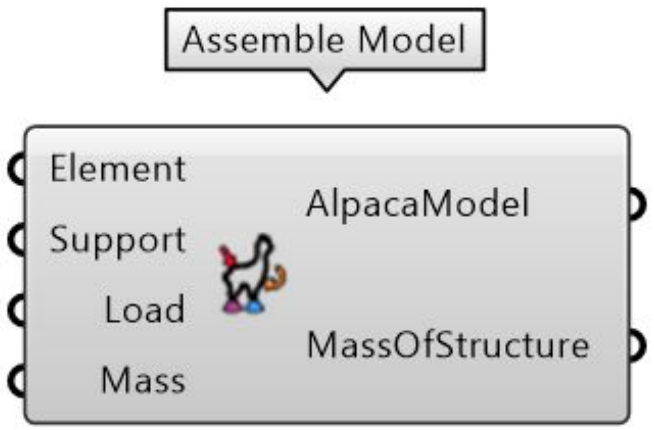
Assemble

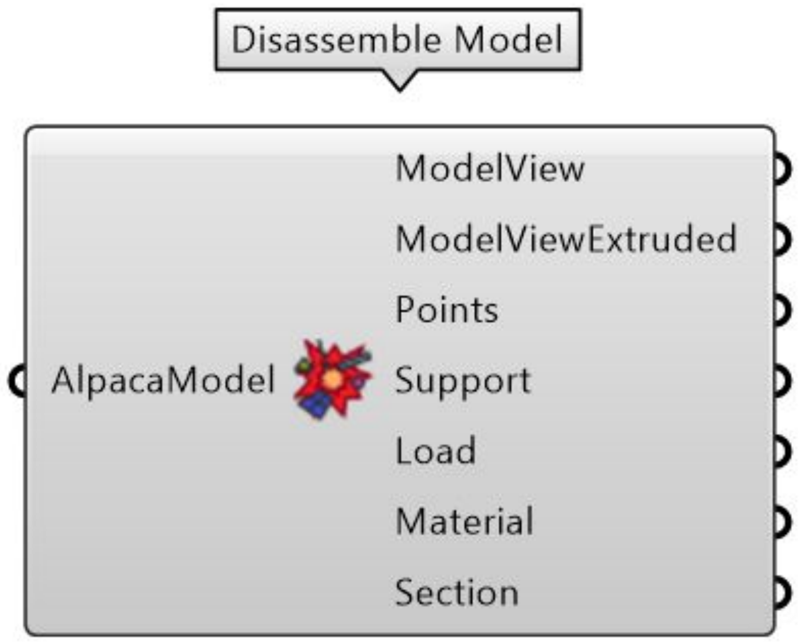
Element and Support are the minimum input that the user should provide to perform an analysis.

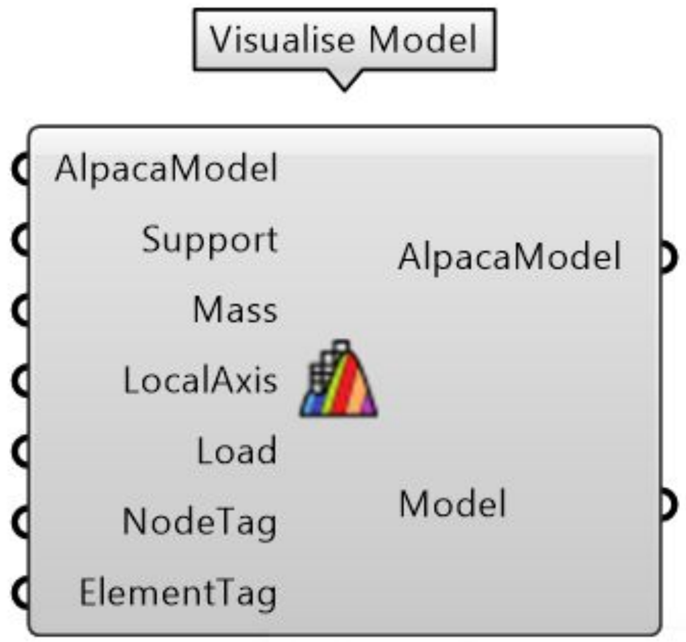
Assemble Model builds a text file with the necessary information to be sent to OpenSees solver. The mass of the structure is automatically calculated from the assemble component.

Disassemble Model retrieves some text information to double check that the model has been assembled correctly.

Visualise Model is a graphical representation of the structure. The model output is either an extruded model or lines model.





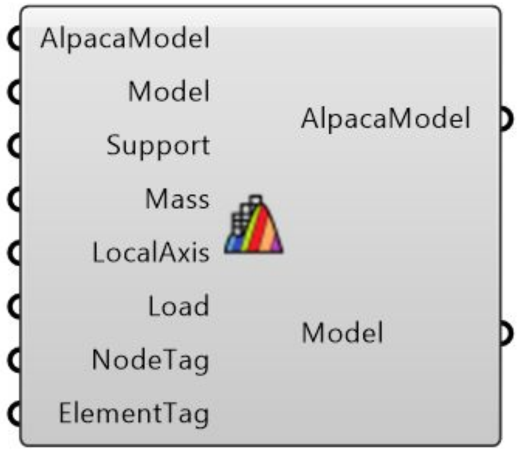


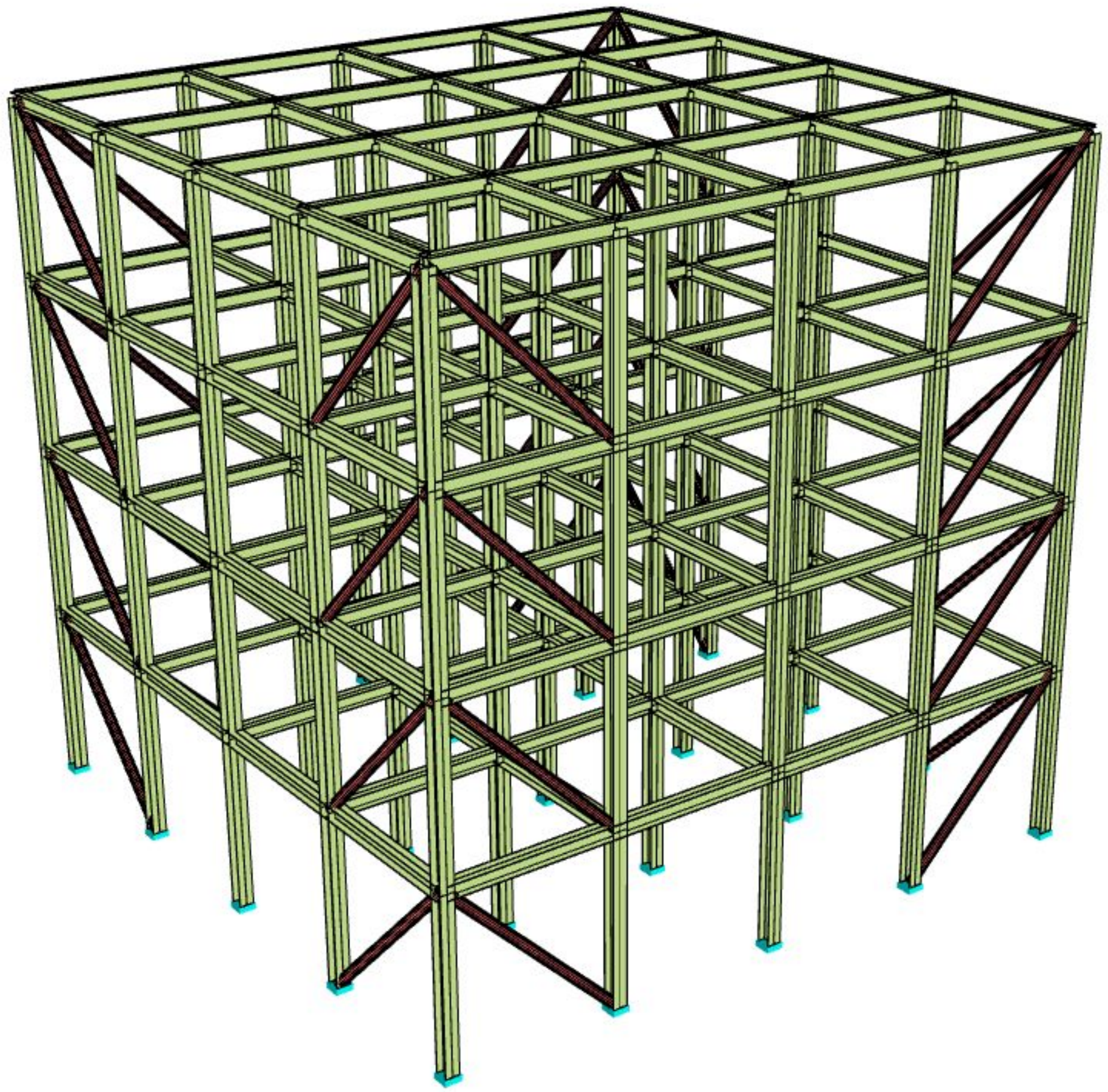
Assemble

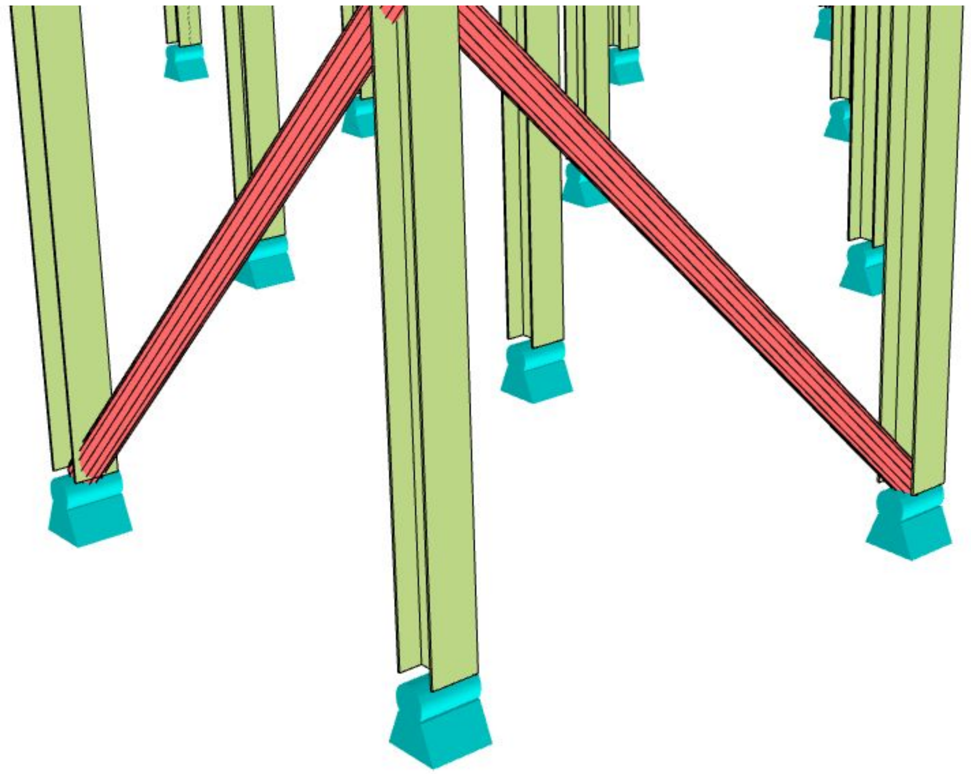
```python
"""Generate a text file model to be sent to OpenSees
    Inputs:
        Element: Structural element.
        Support: Support element.
        Load: Load element.
        Mass: Mass point.
    Output:
       AlpacaModel: Assembled Alpaca model.
       MassOfStructure: Total mass of the structure [kg].
       """

import sys
import clr
import os

import Rhino.Geometry as rg
import Grasshopper as gh

def Assemble(Element, Support, Load, Mass):
    points = []
    startPointList = []
    endPointList = []
    geomTransf = []
    matWrapper = []
    secTagWrapper = []

    for element in Element:
        #print(element[0])
        if (element[1] == "ElasticTimoshenkoBeam") or (element[1] == "Truss"): # element[1] retrieve the type of the beam

            startPoint = element[0].PointAt(element[0].Domain[0])
            endPoint = element[0].PointAt(element[0].Domain[1])
            points.append(startPoint)
            points.append(endPoint)
            geomTransf.append(element[3])
            matWrapper.append([element[2][6][0], element[2][6][1:] ]) # to be careful because we are assigning "unixial" inside the solver. We need to find a clever way to assigning outside
        elif (element[1] == "ShellMITC4") or (element[1] == "shellDKGT"):
            mesh = element[0]
            vertices = mesh.Vertices
            for i in range(vertices.Count):
                points.append( rg.Point3d.FromPoint3f(vertices[i]) )
            matWrapper.append([element[2][2][0], element[2][2][1:] ])
            secTagWrapper.append([element[2][0], element[2][1:] ])
        elif (element[1] == "bbarBrick") or (element[1] == "FourNodeTetrahedron"):
            mesh = element[0]
            vertices = mesh.Vertices
            for i in range(vertices.Count):
                #points.append( rg.Point3d.FromPoint3f(vertices[i]) )
                points.append( rg.Point3d( vertices[i]) )
            matWrapper.append([element[2][0], element[2][1:]])

    # create MatTag
    # use dictionary to delete duplicate
    matNameDict = dict(matWrapper)

    matNameList = []
    i = 1

    for key, value in matNameDict.iteritems():
        temp = [key,i,value]
        matNameList.append(temp)
        i += 1

    openSeesMatTag = []
    for item in matNameList:
        openSeesMatTag.append([ item[0], item[1:] ] )
```

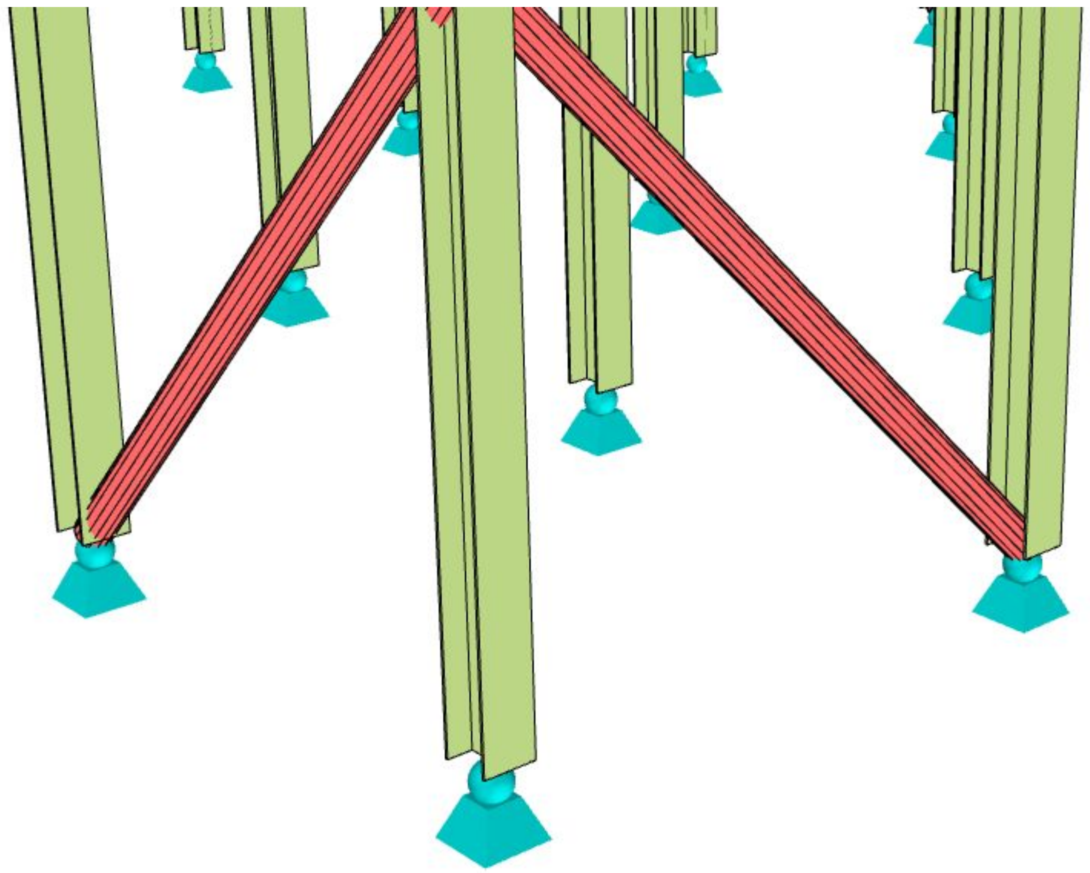
```python
openSeesMatTag = openSeesMatTag
matNameDict = dict(openSeesMatTag)


# create SecTag
# use dictionary to delete duplicate
secTagDict = dict(secTagWrapper)
secTagList = []
i = 1

for key, value in secTagDict.iteritems():
    temp = [key,i,value]
    secTagList.append(temp)
    i += 1

openSeesSecTag = []
for item in secTagList:
    openSeesSecTag.append([ item[0], item[1:] ] )


openSeesSecTag = openSeesSecTag
secTagDict = dict(openSeesSecTag)

#print(secTagDict)

# create GeomTransf
geomTransf = [row[0] for row in geomTransf ]
geomTransfList = list(dict.fromkeys(geomTransf))
geomTransfDict = { geomTransfList[i] : i+1 for i in range(len(geomTransfList) ) }

geomTag = geomTransfDict.values() # elemento a dx (tag)
geomVec = geomTransfDict.keys() # elemento a sx (vettore)

GeomTransf = []
for i in range(0, len(geomTag) ) :
    GeomTransf.append( [ geomTag[i], list(rg.Vector3d(geomVec[i])) ] )

GeomTransf = GeomTransf



oPoints = rg.Point3d.CullDuplicates(points, 0.01)        # Collection of all the points of our geometry
cloudPoints = rg.PointCloud(oPoints)         # Convert to PointCloud to use ClosestPoint Method


## FOR NODE ##
openSeesNode = []

for nodeTag, node in enumerate(oPoints):
    openSeesNode.append( [nodeTag, node.X, node.Y, node.Z] )

openSeesNode = openSeesNode


## FOR ELEMENT ##

openSeesBeam = []
openSeesShell = []
openSeesSolid = []
MassOfStructure = 0
for eleTag, element in enumerate(Element):
    if (element[1] == "ElasticTimoshenkoBeam") or (element[1] == "Truss"): # element[1] retrieve the type of the beam
```

Visualise


AlpacaModel
Model
Support
Mass
LocalAxis
Load
NodeTag
ElementTag
AlpacaModel
Model





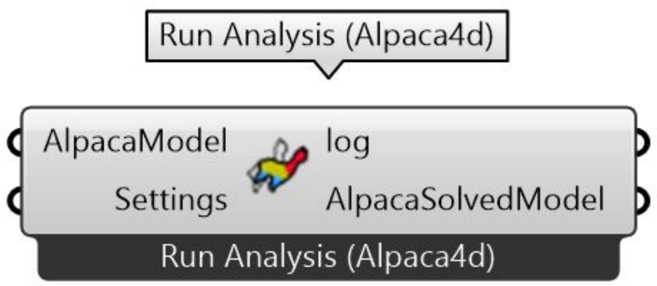


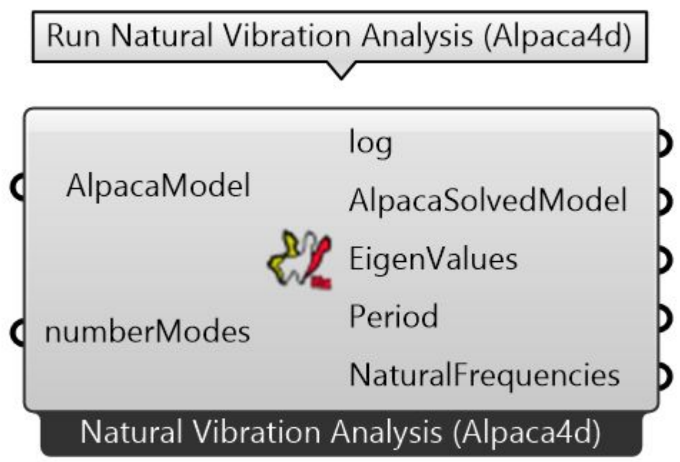
Analysis

Alpaca 4d can perform Static Analysis, Modal analysis, Ground Motion Analysis and 3NDF Analysis (WIP-Brick Elements).

Static Analysis computes the response of the structure.

Modal Analysis computes the Modal shapes of the structure and returns the period and frequency of that mode.

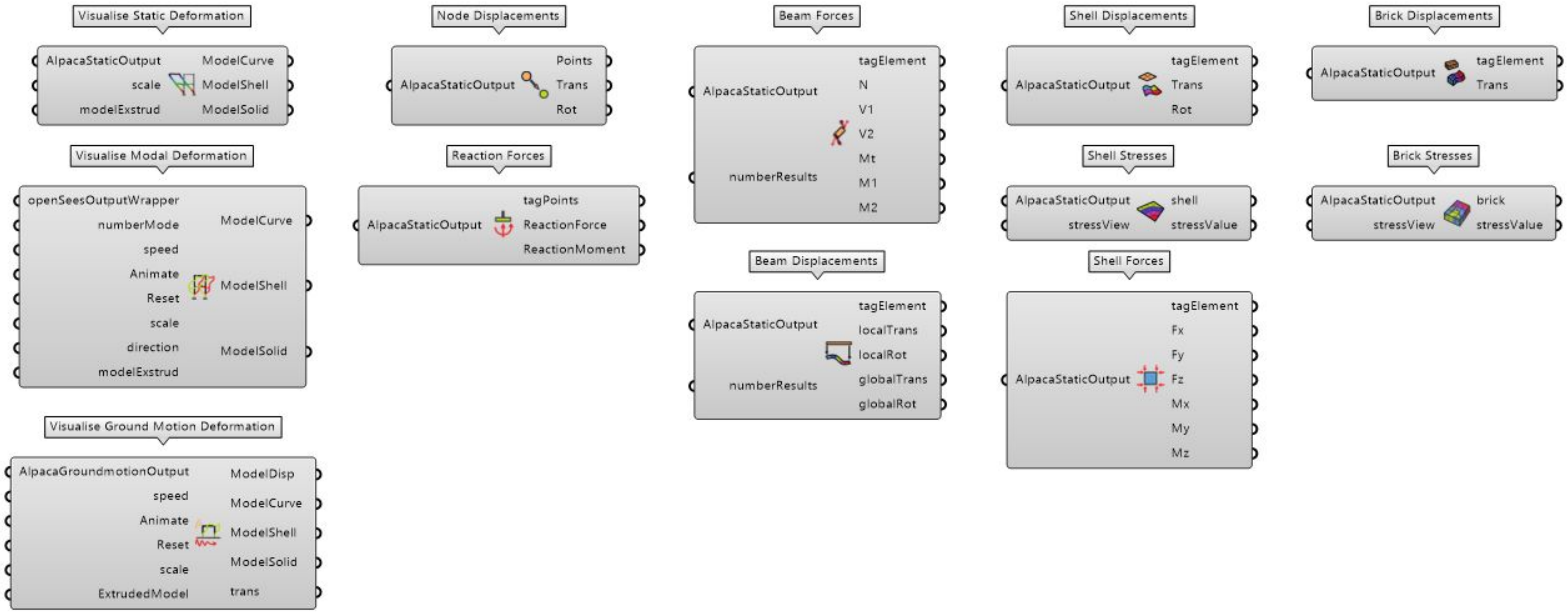




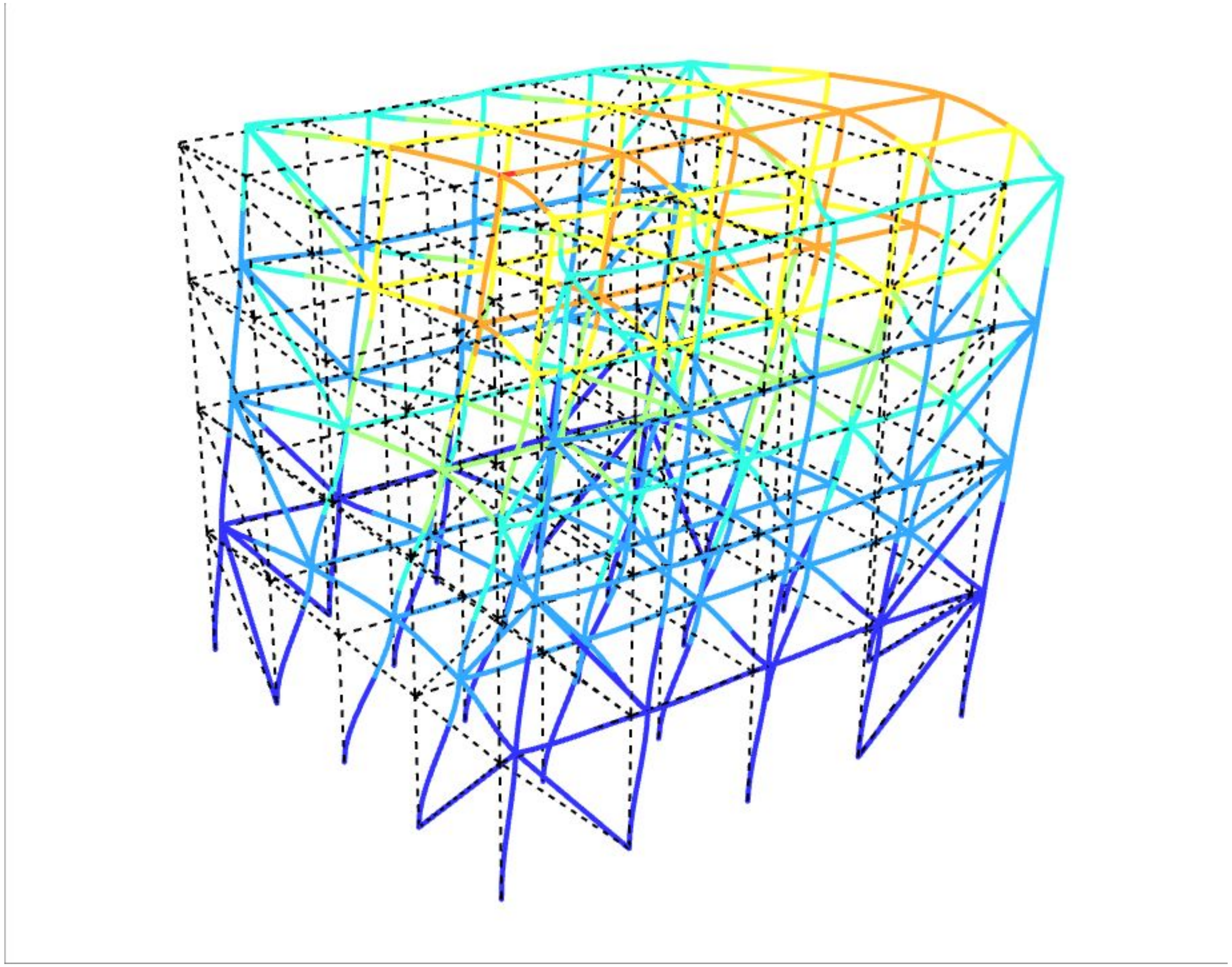
Numerical Computation and Visualization

The static analysis returns the numerical outputs to study the behaviour of the structure. It is possible to query results for Point, Beam, Shell and Brick elements.

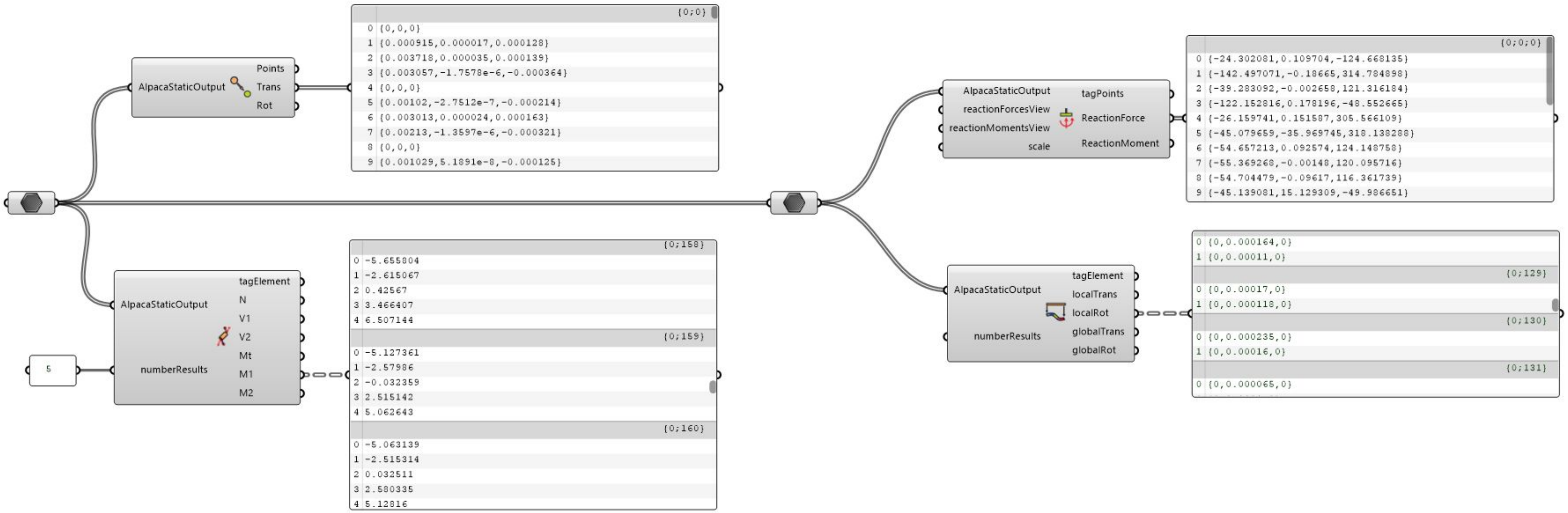
The visualization tool has been implemented for all types of analyses.



Numerical Computation and Visualization



Numerical Computation and Visualization



Numerical Computation and Visualization

Pro

Open-Source code in C++

Complex Analysis:

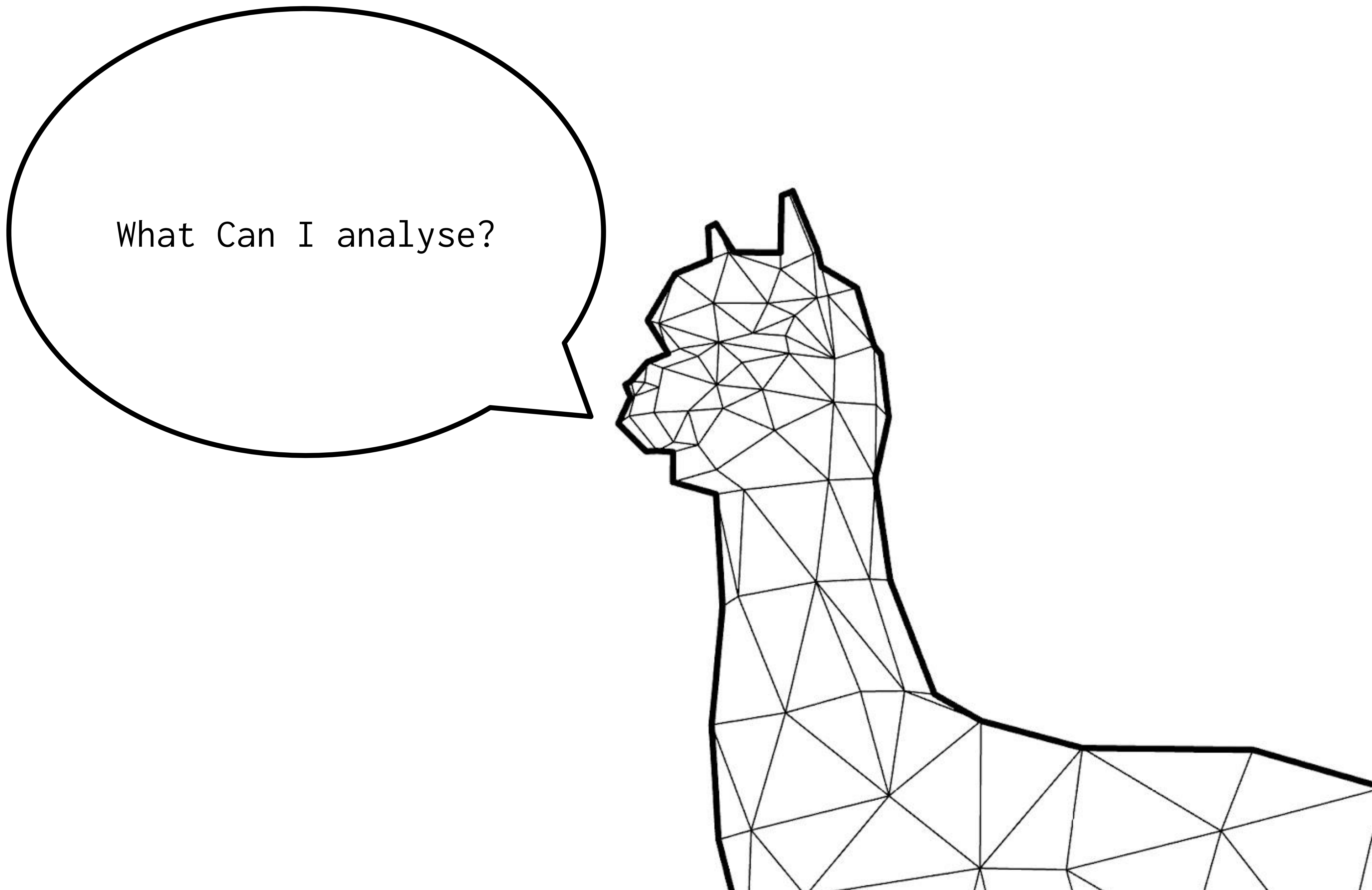
- Linear
- Non linear
- Static
- Dynamic

In the process of validation

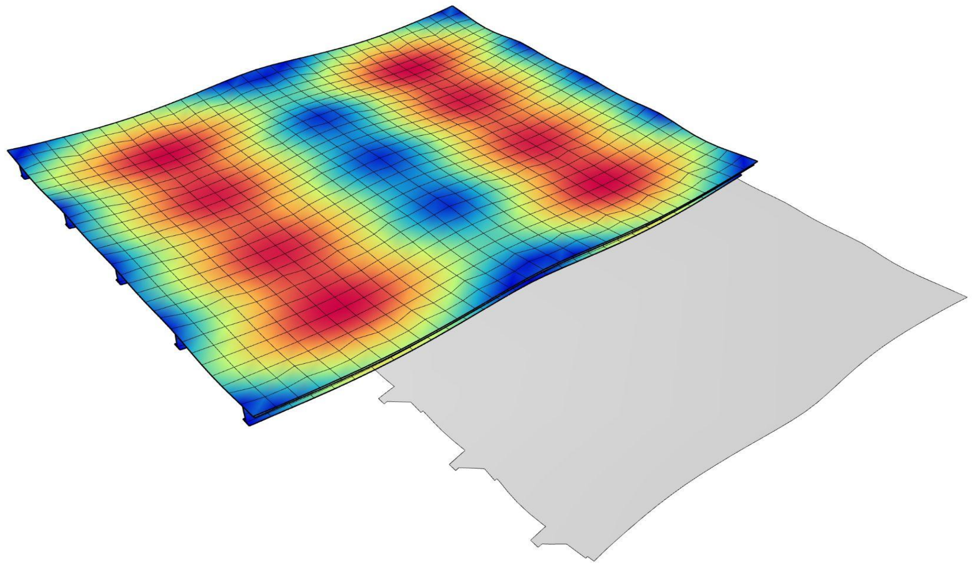
User in Academia (i.e. UCL)

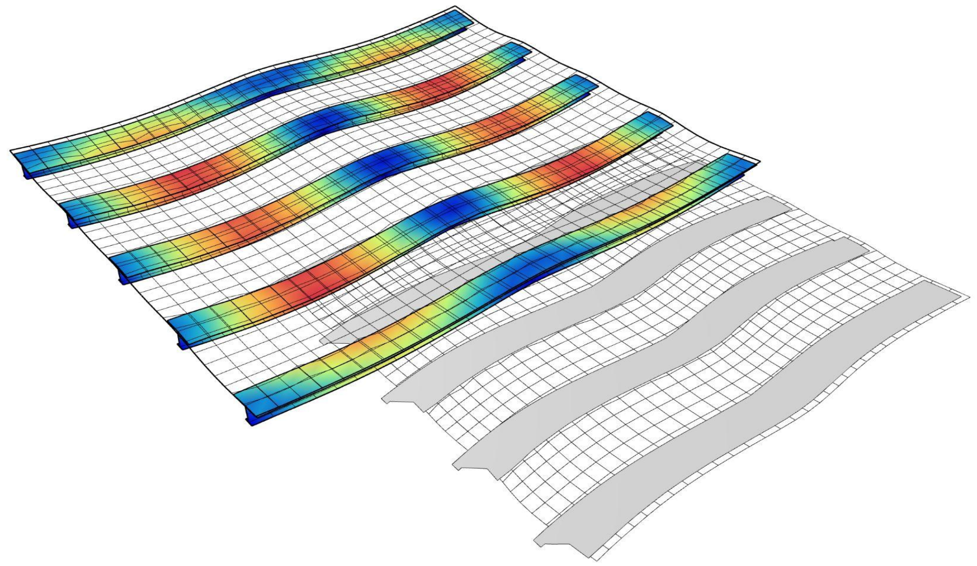
Cons

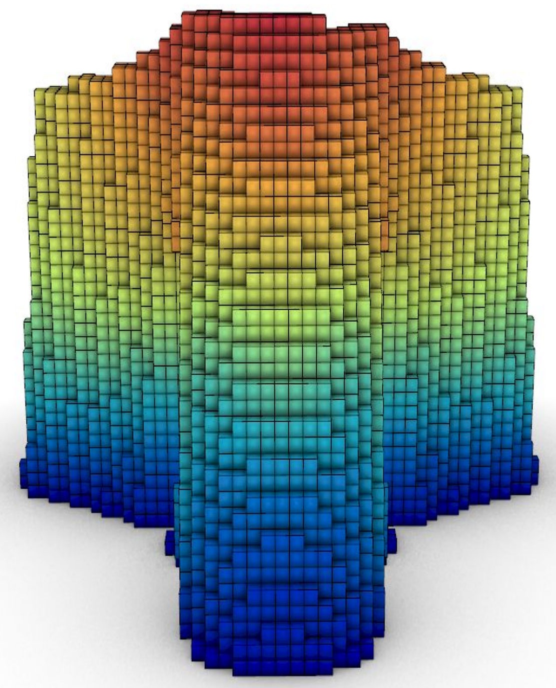
Slow (for now)

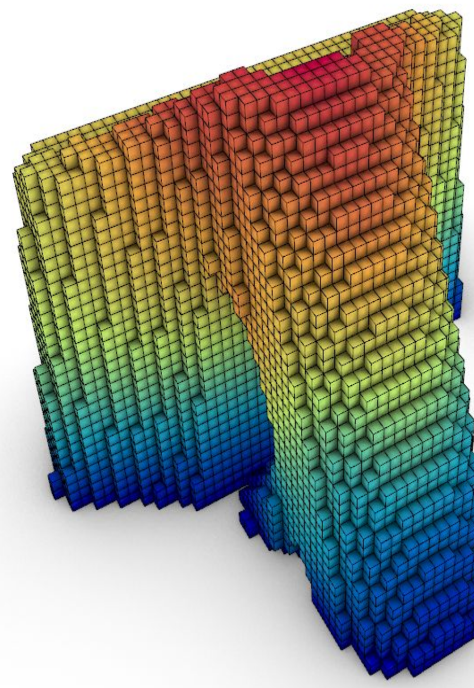

What Can I analyse?

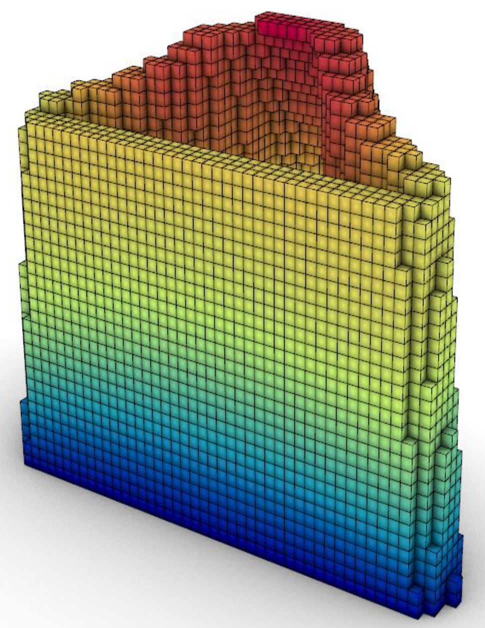
Examples



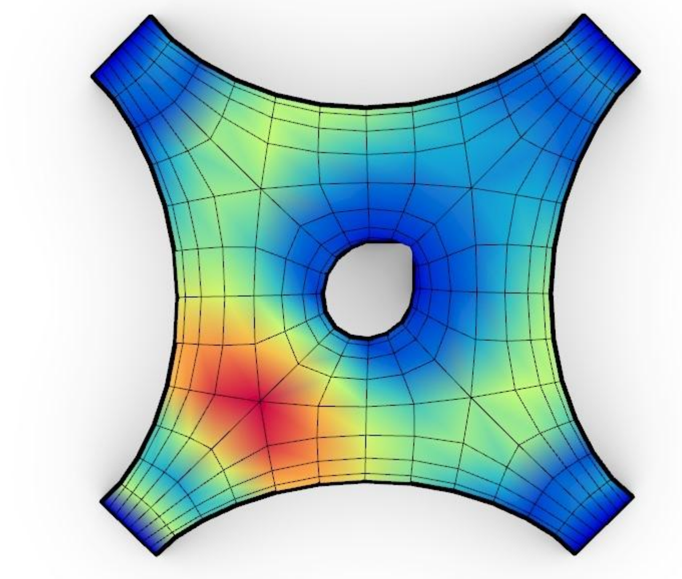


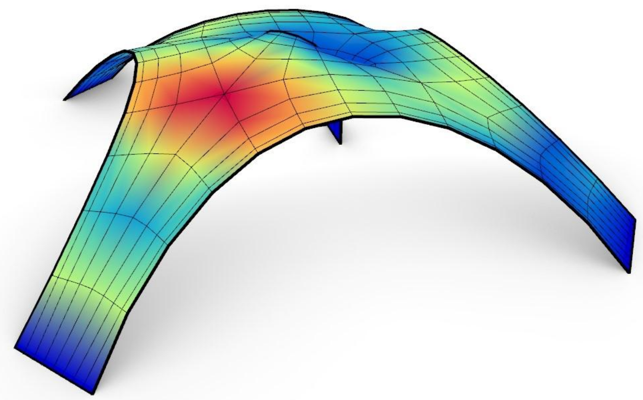


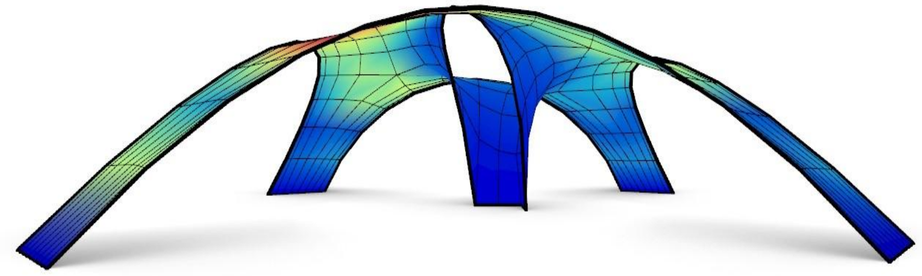


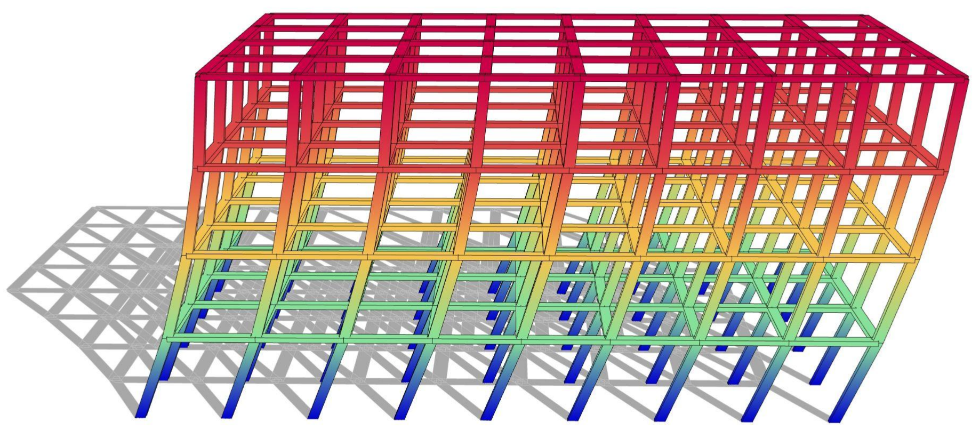


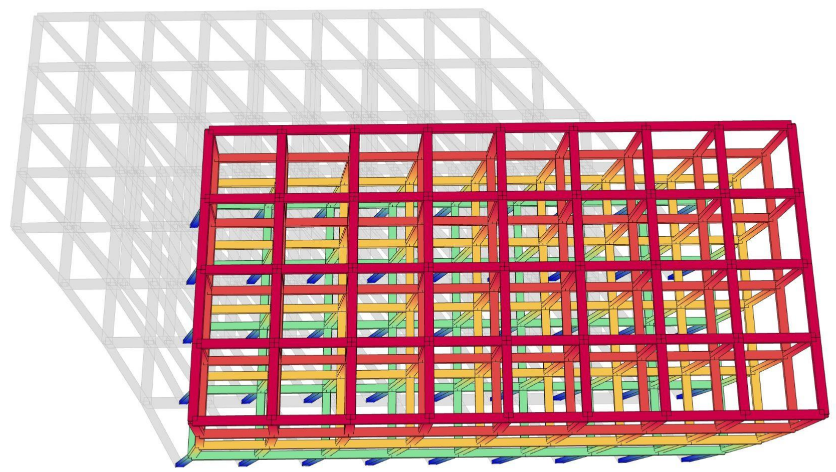
Examples

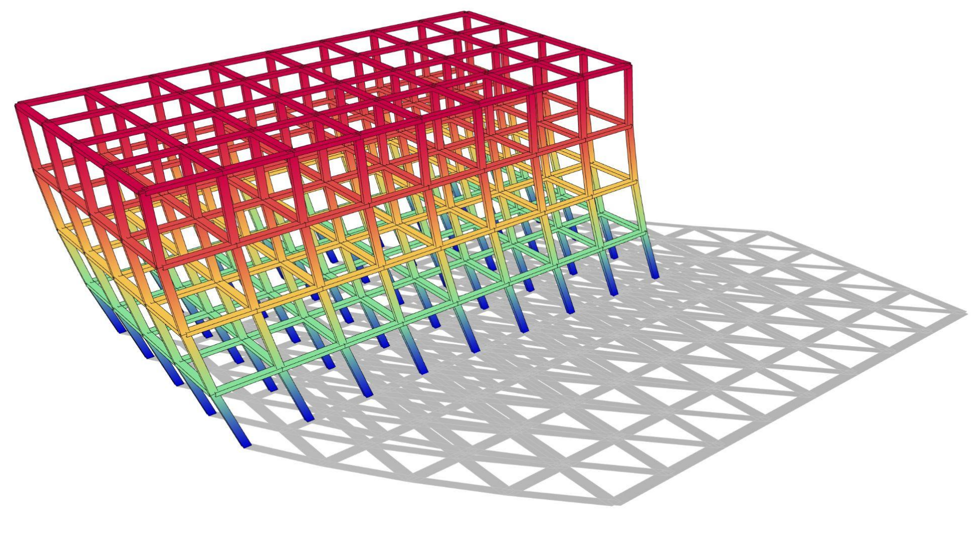




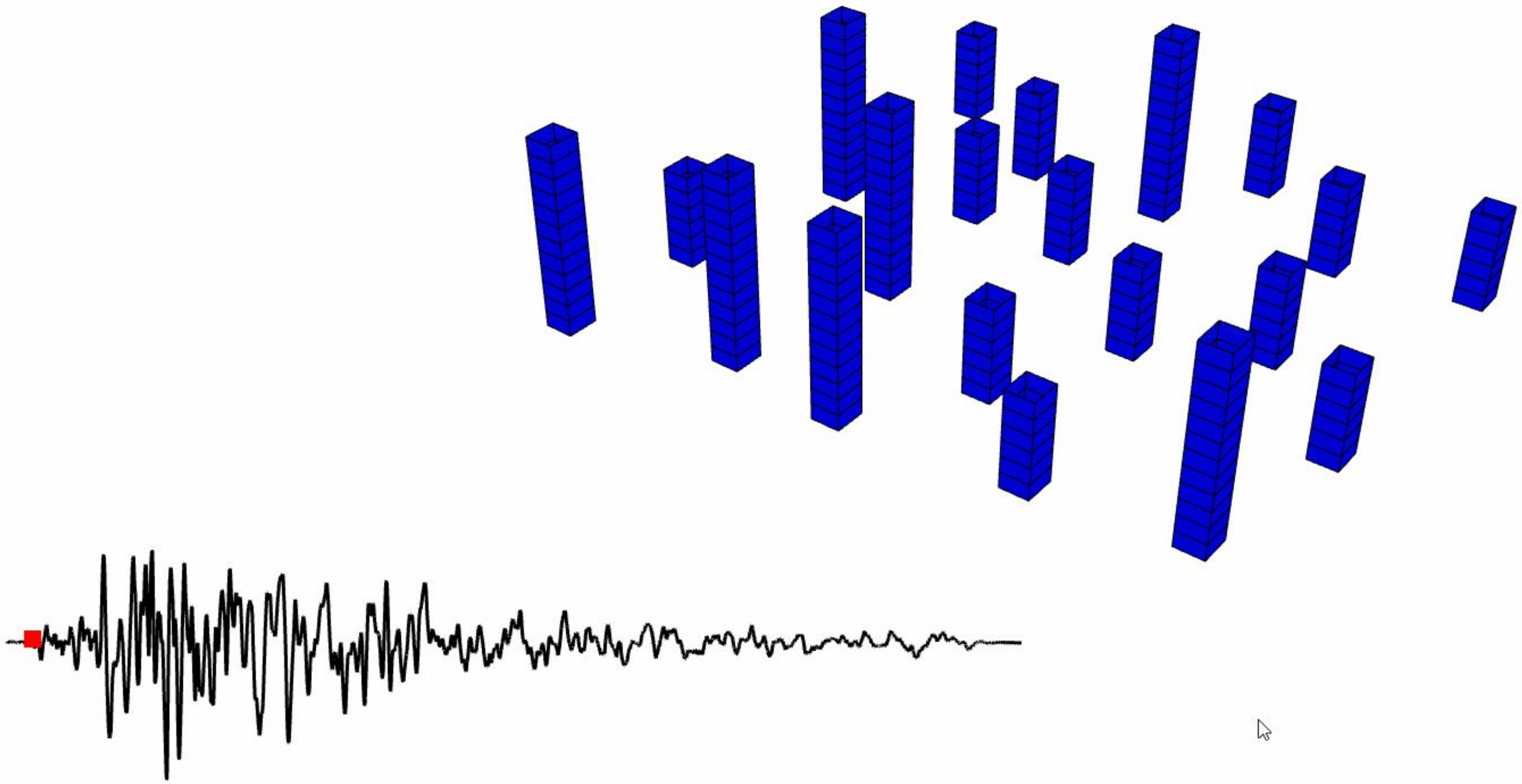








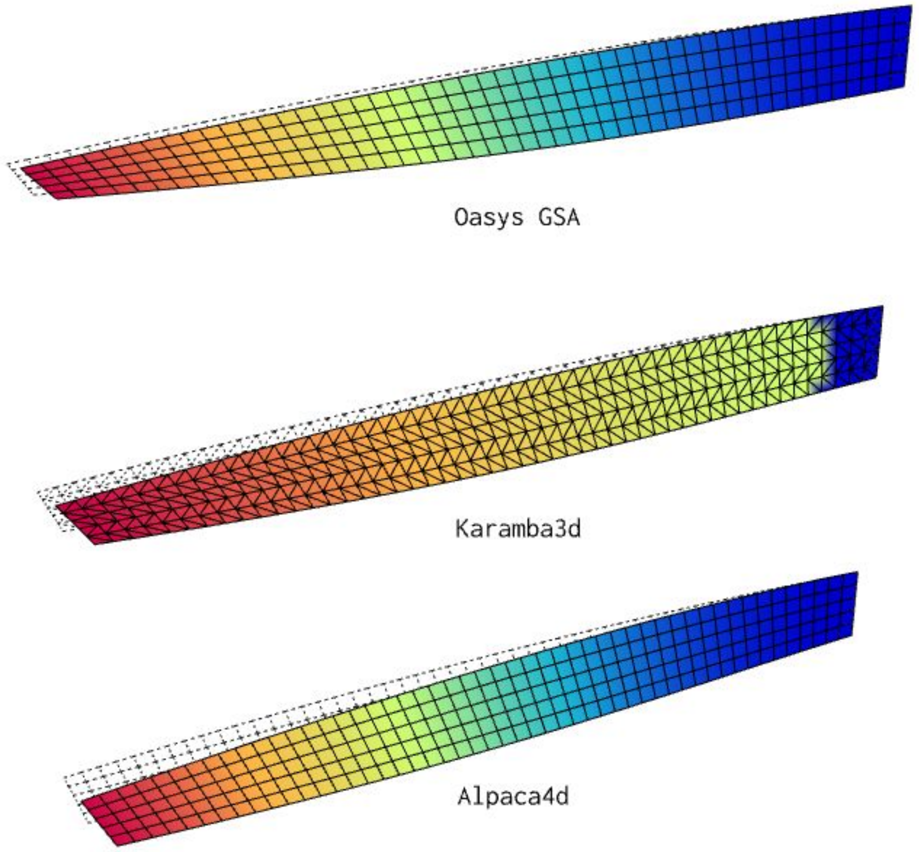
Examples



Benchmark

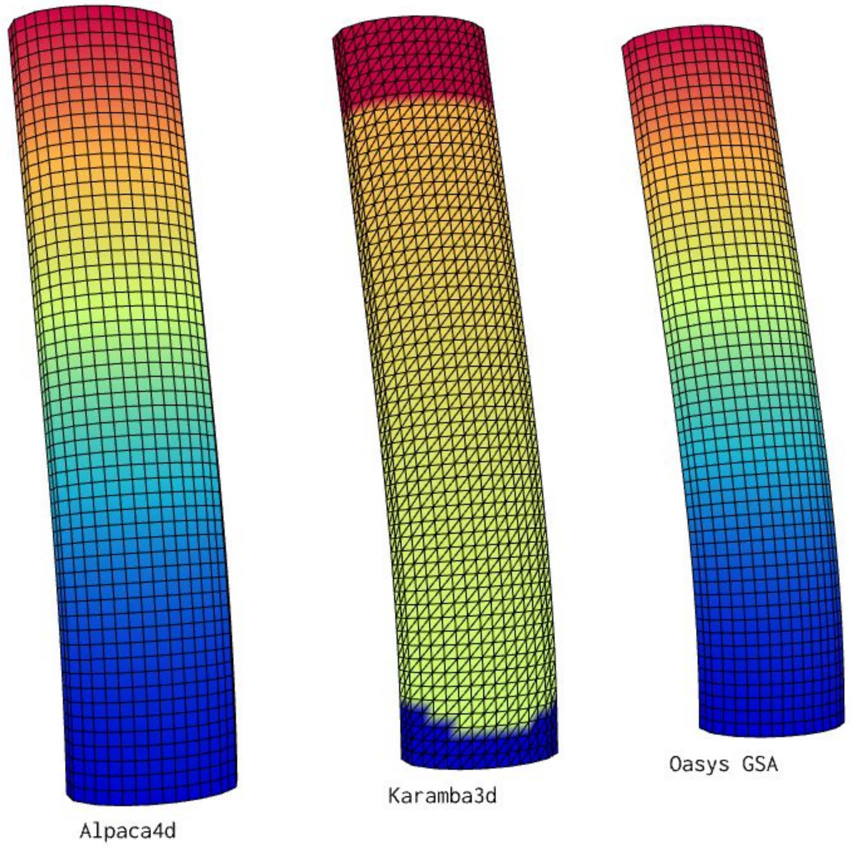
Displacement

Alpaca4d: 5.69 mm
Karamba3d: 6.04 mm
Oasys GSA: 4.14 mm



Displacement

Alpaca4d: 18 mm
Karamba3d: 18 mm
Oasys GSA: 18 mm



Analytical solution = 5.68 mm

WIP

Technical aspect

- Adding Elements type
- Adding Load type
- Acquiring data for Machine Learning purpose
- Outputting Stress Utilisation for elements

Environmental aspect

- Embodied Carbon tool

Belief

- Better Design for a better world

alpaca4d.github.io

Alpaca4d