Substructuring

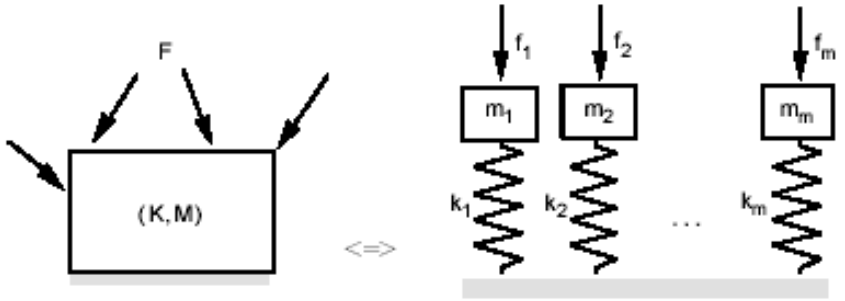
Code_Aster, Salome-Meca course material

What is Substructuring ?

- Extension of modal superposition method
- Why substructuring ?
  - reduce CPU time
  - reduce memory demand
- Substructuring in Dynamics = substructuring + modal reduction
- Main methods :
  - Craig-Bampton
  - Mc-Neal
  - Modes on interfaces
- Symetry of revolution – « cyclic substructuring »

Modal reduction

- Ritz method : projection on a reduced basis



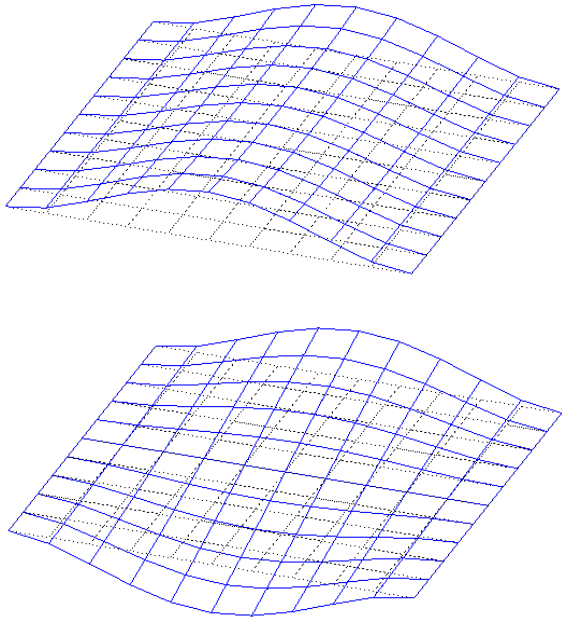
- Linear dynamics : **modal** basis + **static correction terms**
  - Estimated displacement : $\widetilde{U}(t) = \sum_{i=1}^{n} \eta_i(t) \Phi_i$
  - Equation of dynamics : $\mathbf{M}\ddot{U} + \mathbf{C}\dot{U} + \mathbf{K}U = \mathbf{F}$
  - Projections : $\Phi_i^T \mathbf{M} \Phi_j = m_i \ \delta_{ij} \qquad \Phi_i^T \mathbf{K} \Phi_j = k_i \ \delta_{ij}$
  - Reduced problem **(orthonormalised basis)**

$$\begin{pmatrix} \backslash & 0 & 0 \\ 0 & m_i & 0 \\ 0 & 0 & \backslash \end{pmatrix} \ddot{\eta} + \Phi^T \mathbf{C} \, \Phi \, \dot{\eta} + \begin{pmatrix} \backslash & 0 & 0 \\ 0 & k_i & 0 \\ 0 & 0 & \backslash \end{pmatrix} \eta = \Phi^T \mathbf{F}_{ext}$$

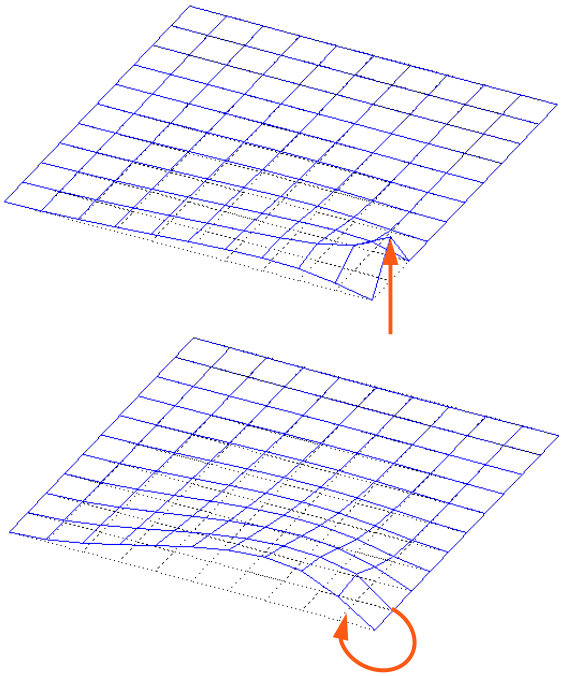
Craig-Bampton Method

- Constitution of the basis :
  - Eigenmodes with **fixed interface**
  - Static «constrained» modes (one for each DOF) :
    All DOFs are held fixed except one constrained displacement (equaled to one)

Fixed interface modes



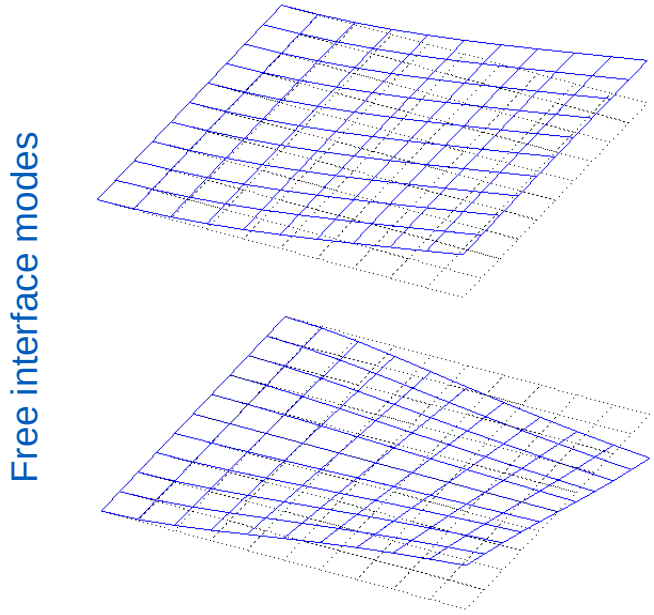
Constrained « modes »

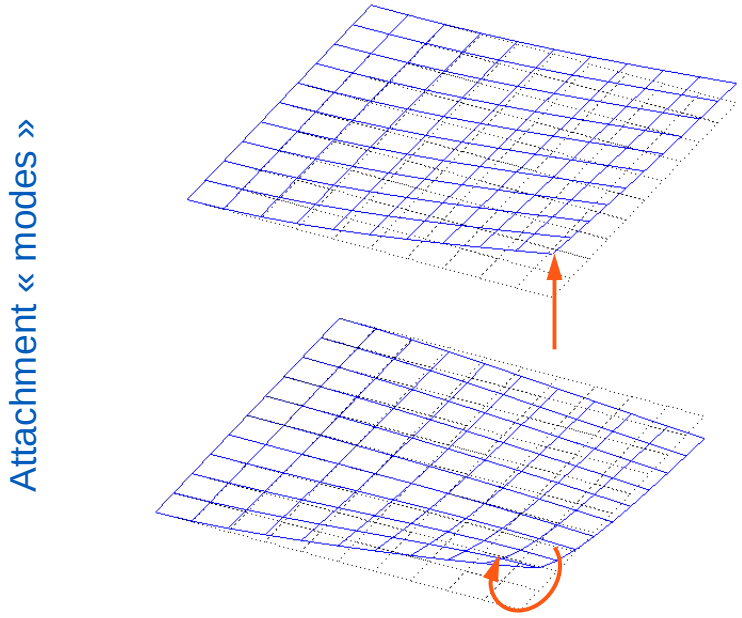


- Interesting from a numerical point of view
- Experimental comparison is not easy (Fixed boundary conditions are difficult to meet)

Mc Neal Method

- Constitution of the basis:
  - Eigenmodes with **free interface**
  - « Attachment » modes (one for each DOF) :
    All DOFs are free except one with an applied unitary force





- Interesting from an experimental point of view
- Eigenmodes can be strongly colinear with attachment modes

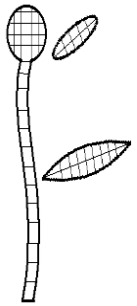
Method of Modes on Interfaces

- Compute only relevant constrained modes / attachment modes
  - Limit the size of the bases when the number of interface DOF increase
- Based on the spectral properties of the dynamical system, reduced on the interfaces
- Eigenmodes computed on the interfaces
  - **MODE_STATIQUE** with keyword **MODE_INTERF**
- Macro-elements on each substructure :
  - Normal modes + Interface modes
- « Incompatible » interfaces are admitted
  - 2D/3D, non corresponding nodes on the interface, linear/quadratic, etc.

Main steps for substructuring 1/2

LIRE_MAILLAGE
AFFE_MODELE
AFFE_MATERIAU
AFFE_CHAR_MECA

Data
- *Mesh*
- *Material properties*
- *Boundary conditions*
- *Loads*



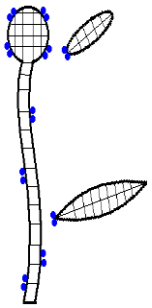
Define the interfaces

Compute fixed/free modes

Compute constraint / attachment / interface modes

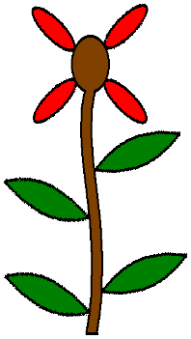
Assemble the macro-elements

CREA_ELEM_SSD



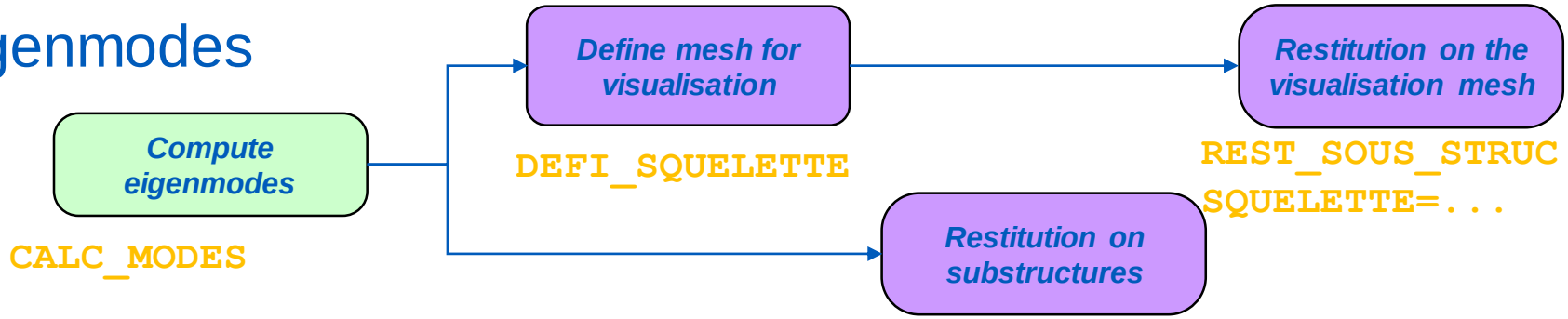
Build the reduced model

ASSE_ELEM_SSD



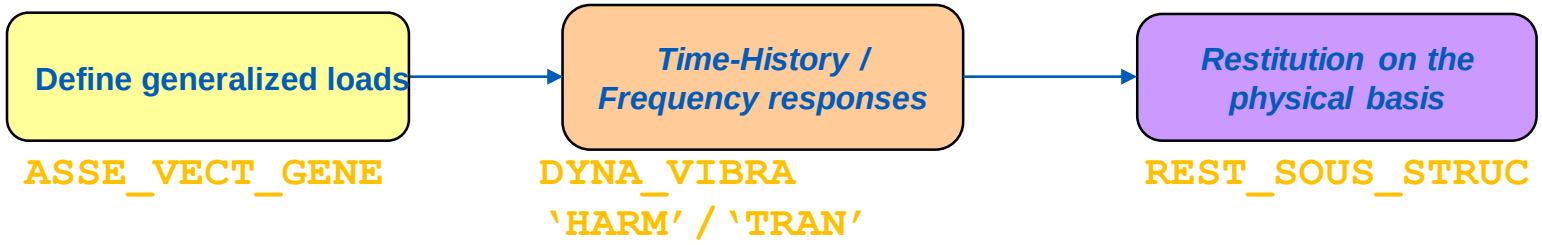
Main steps for substructuring 2/2

Eigenmodes

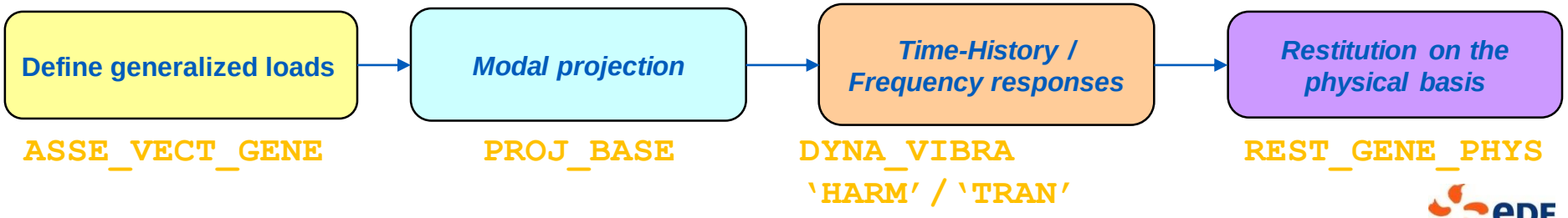


Responses

« standard » way

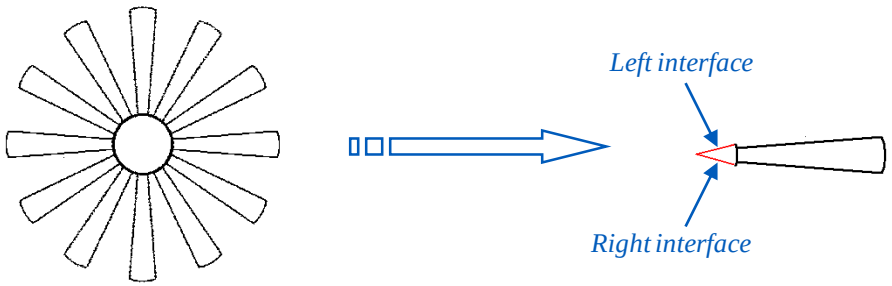


« historical » way – not recommended



Substructuring for systems with revolution-type symmetry

- Nodal circles and diameters
  - Nodal circle : circle where displacements are zero
  - Nodal diameter : diameter where displacements are zero
- Same two methods : Craig Bampton & Mc Neal
- Specific command : **MODE_ITER_CYCL**



Advices

- Read the reference documentation
  - [R4.06.02] « Modal analysis with classical dynamic substructuring »
  - [U2.06.04] « Notice for the construction of reduced dynamic models »
- Classic Methods (Craig & Bampton, McNeal) are efficient for small interfaces
- For interfaces with many DOFs => Method of Interfaces Modes
  - Quality estimation of the reduced model (eigenmode computation) ➔ `CALC_CORR_SSD`
  - See associated documentation : [U4.52.16]