Finite Element Method for FAD mechanics

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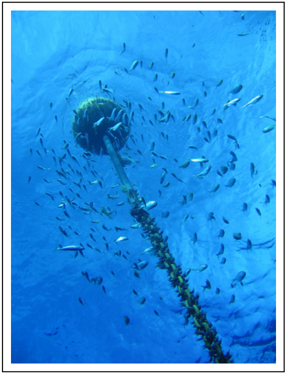
PROGRAMME INTERREG CARAÏBES
l'Europe s'engage avec les Antilles-Guyane dans la Grande Caraïbe

Problem

Mechanical behaviour of complex flexible marine structures



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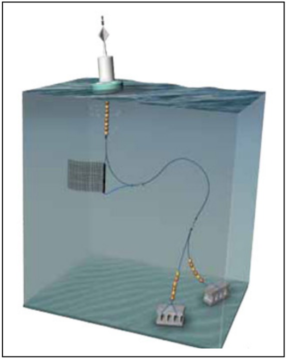

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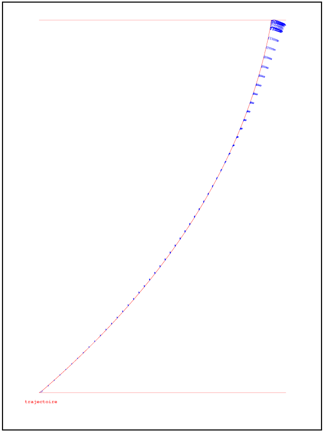
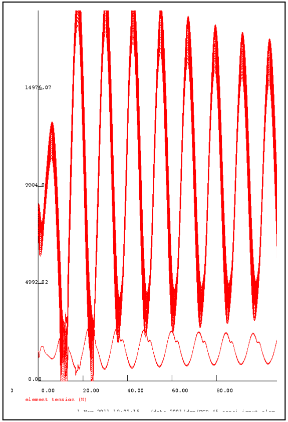
Objective



Shape of the FAD, Displacement in wave.



Cable tension.

Finite Element Method

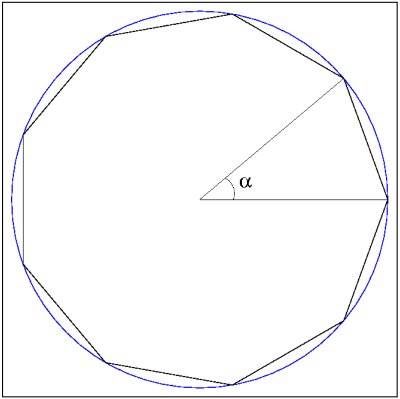
FEM modelling for complex structures
used for the mechanical behaviour.

Principle:

- Split the structure in small elements,
- Approximation in these small elements,
- Re-build the structure.

A simple example: Circle perimeter

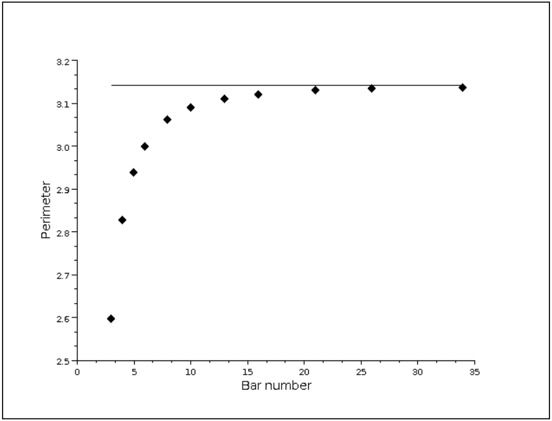
- Perimeter is $2\pi R$
- Perimeter split in n arc length
- Arc length approximated by cord length
- Cord length $2Rsin(\frac{\alpha}{2})$
- Perimeter n times arc length



Circle perimeter

$R = 0.5$
$Perimeter = \pi$

More of bars elements, better the accuracy.



Perimeter vs elements number

Equation of the mechanics

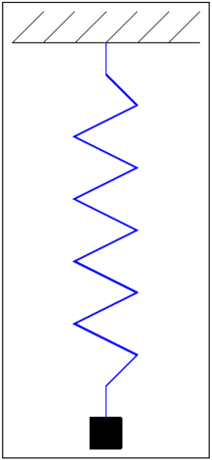
- Equilibrium of forces leads to position
- $\mathbf{f} - \mathbf{m}\gamma = \mathbf{0}$
- nodes are extremities of elements
- Equilibrium : $\mathbf{F}(\mathbf{X}) = \mathbf{0}$
- But $\mathbf{F}(\mathbf{X}_{init}) \neq \mathbf{0}$

Vector of position and force

- Vector of position $\mathbf{X}$
- Vector of force $\mathbf{F}$ depends on $\mathbf{X}$
- How to find $\mathbf{X}_{final}$ such that $\mathbf{F}(\mathbf{X}_{final}) = 0$?

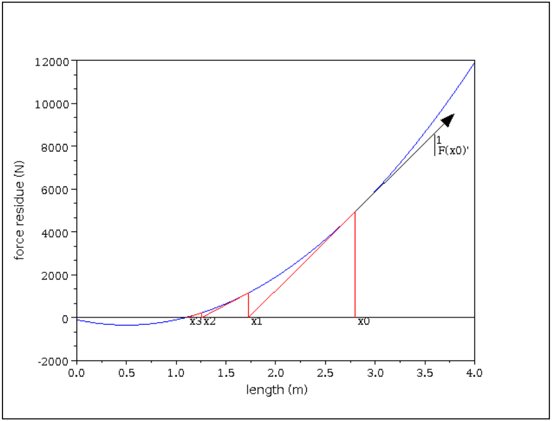
Spring with 1DOF

- $F(x) = Ax^{\frac{x-l_0}{l_0}} - Mg$
- Stiffness not constant
- What is the length (x) at equilibrium?
- Equilibrium: $F(x) = 0$



Spring with 1DOF

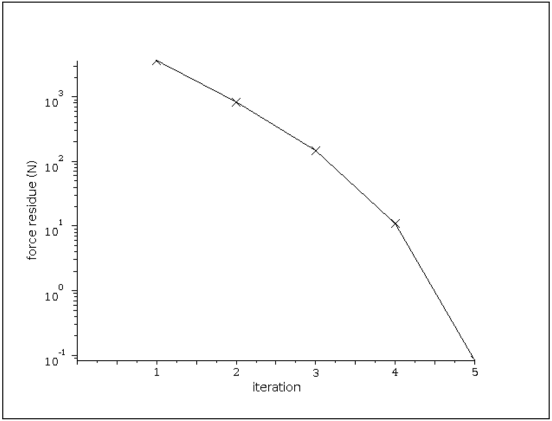
$$x_{k+1} = x_k + \frac{F(x_k)}{-F'(x_k)}$$
$$F'(x) = \lim_{h\to 0} \frac{F(x+h)-F(x)}{h}$$



Force residue vs length (X)

Spring with 1DOF

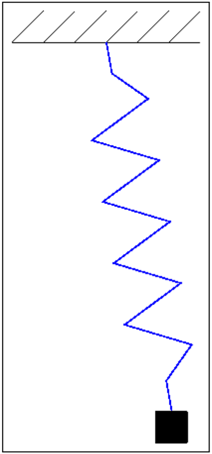
Convergence is quick



Force residue vs iterations

Spring with 2DOF

- $F_x(\mathbf{X}) = T\frac{x}{l}$
- $F_y(\mathbf{X}) = T\frac{y}{l} - Mg$
- $T = Al\frac{l-l_0}{l_0}$ Stiffness not constant
- $l = \sqrt{x^2 + y^2}$



Spring with 2DOF

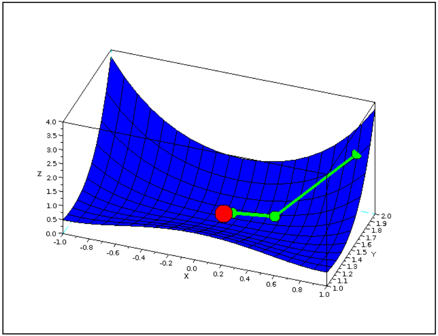
$$\mathbf{X}_k = \begin{cases} x_k \\ y_k \end{cases}$$

$$\mathbf{F}(\mathbf{X}_k) = \begin{cases} F_x(\mathbf{X}_k) \\ F_y(\mathbf{X}_k) \end{cases}$$

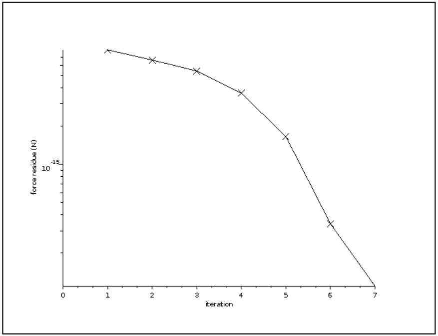
$$F'(\mathbf{X}_k) = \frac{A}{l_0 l_k} \begin{cases} l_k^2 - l_0 l_k + y_k^2 & x_k y_k \\ x_k y_k & l_k^2 - l_0 l_k + y_k^2 \end{cases}$$

$$\mathbf{X}_{k+1} = \mathbf{X}_k + \frac{\mathbf{F}(\mathbf{X}_k)}{-F'(\mathbf{X}_k)}$$

Spring with 2DOF



Force norme



Force residue vs iterations

Adaptation to FAD

Cables split in bar element

- Bar elastic
- Bar straight
- Length
- Diameter ...

Floats approximated by parallelepiped

- Mass
- Volume ...

Forces on FAD

Forces $\mathbf{F}$ depend on node position $\mathbf{X}$

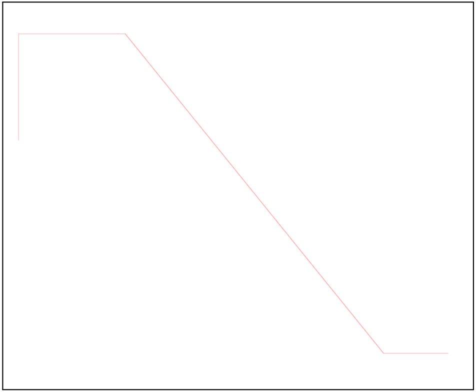
- Tension
- Weight
- Floatability
- Drag
- Dynamic
- Bottom contact

- $T_e = \frac{l-l_0}{l_0} AE$
- $W_e = Mg$
- $F_l = V\rho g$
- $D_r = \frac{1}{2}\rho CdSV^2$
- $I_n = -M\gamma$
- $B_o = (Z_b - Z)K_b$

$$\mathbf{F} = T_e + W_e + F_l + D_r + I_n + B_o$$

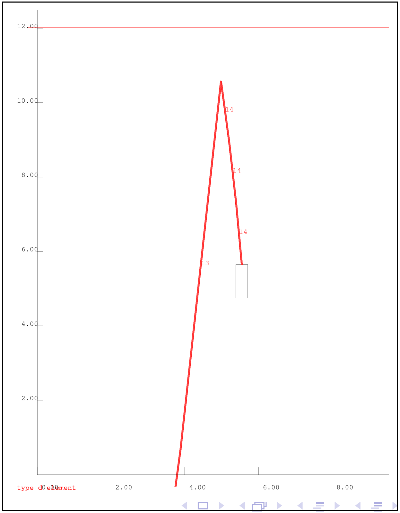
Cable input

```
number of cables             :14

cable                        :1
extremities no x y z type    :
1 0 0 -1500 1
2 20 0 -1500 2
traction stiffness (N)       :3923000
compression stiffness (N)    :0
length (m)                   :20
density (kg/m3)              :1050
diameter (m)                 :0.044
cd                           :1.2
f                            :0.08
element number               :3
node type                    :2
```



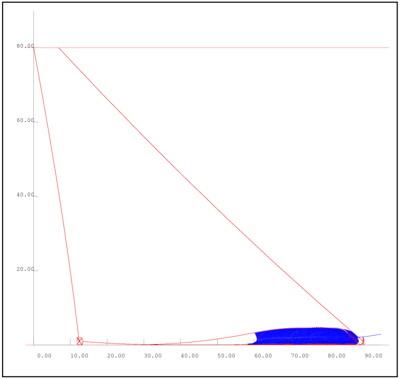
Environment input

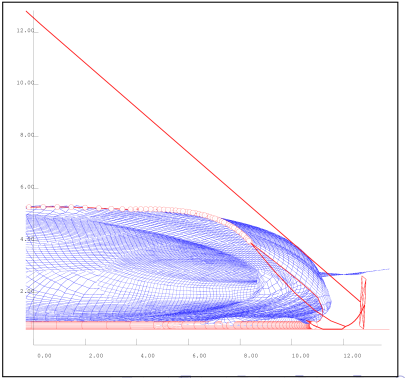
```
current direction (deg)    :45
current amplitude (m/s)    :1.0

wave period (s)            :12.0
wave height (m)            :20.0
wave direction (deg)       :0
```



Trawl

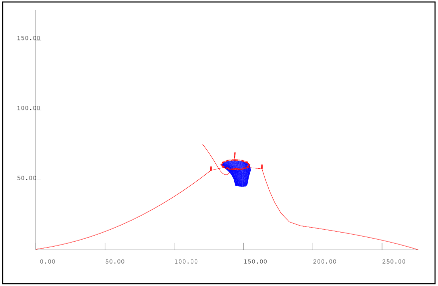
Bottom trawl:
Netting, cables, floats, doors.

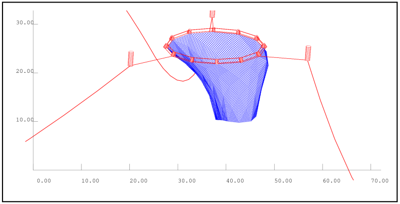




Fish cage

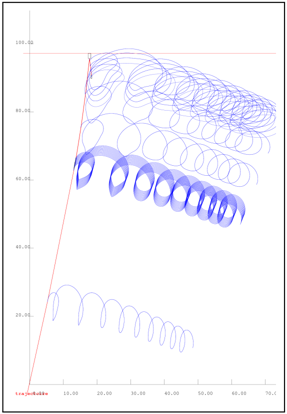
Circular cage moored with 3 chains:
Netting, cables, floats, chains.



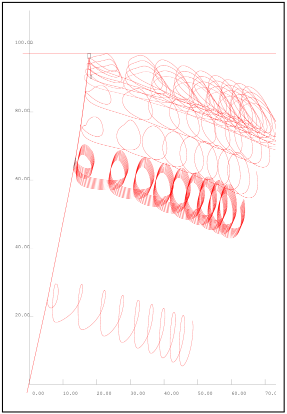


FAD behaviour

Mechanical behaviour of the FAD in waves



Displacement



Immersion

Discussion

- Few current levels vs one level
- Large wave spectra vs Airy wave
- Accuracy: bar length (1m, 10m)
- Accuracy: time step (0.01s, 0.1s)
- Drag coefficient (1.2, 1.8) : flume tank tests
- Complex structures (plastic sheets) : flume tank tests
- Cable flexion

Thank you for your attention