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Physically Based Animation of Sea Anemones in Real-Time

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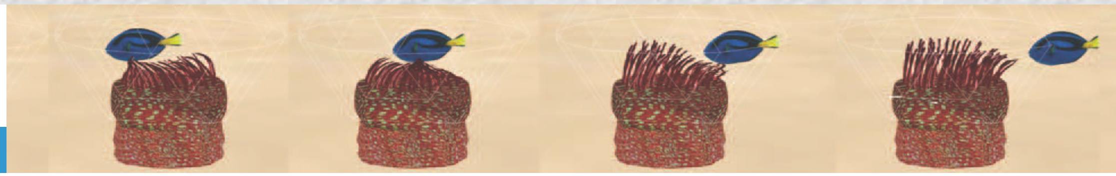
POLITÉCNICA



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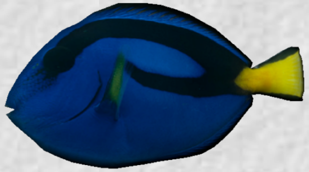
Motivation

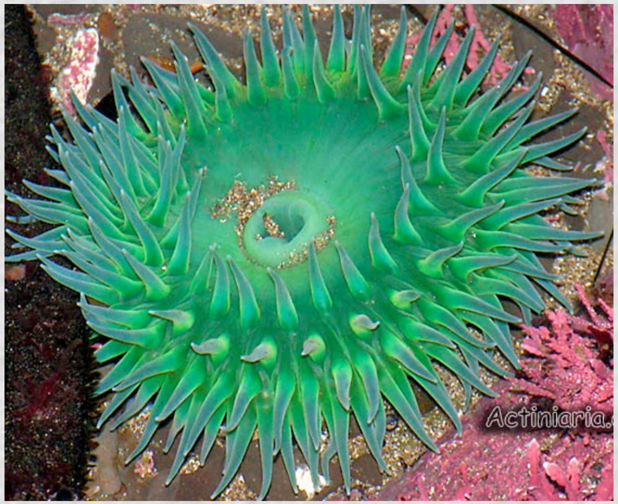
- Sea Anemones :
  - Important component of seascapes
  - Made of two parts: foot and tentacles
  - Interact with the surrounding fluid
  - Interact with other entities (fish)



- Lack of real-time technique (virtual environment, video games)
- Aim: propose a real-time technique, physically based, with high level control

Sea Anemones in Nature

- Come in many shapes, sizes, colors
- Composed of a foot attached to the rock / sand of constant volume
- Tentacles attached atop arranged in cycle (spiral phyllotaxis)
  - Defense mechanism, trap
  - React to fish



Sea Anemones in Nature

- Come in many shapes, sizes, colors
- Composed of a foot attached to the rock / sand of constant volume
- Tentacles attached atop arranged in cycle (spiral phyllotaxis)
- Stay in place for days, months, swaying in the fluid, reacting to fish

Outline

- Related work
- Overview of our technique
- Fluid description
- Anemone model
- Deformation of fibers
- Results
- Conclusion & Future Work

Related Work

- Modeling of the *Stromphia Coccinea* [Liang 01]
  - Implicit Surfaces (Blob Tree [Wyvill 99])
    - Prohibitive rendering times
  - Tentacles implantation using a phyllotaxis model
- Animation as a reaction to the starfish [Nur 01]
  - Focuses on the general behavior
  - Deformation of foot and tentacles keyframed

Related Work (2)

- **Animation of grass blades using and internal skeleton deformed by**
  - **IK-like techniques [Bakay 02, Ota 04]**
  - **Blending of pre-computed key poses [Perbet 01, Endo 03]**

  ⇒ **Manual specification / keyframing of the deformation of individual fibers**
- **Animation of trees using procedural stochastic techniques [Stam 97]**

  ⇒ **Interaction with entities such as fish difficult**

Related Work (3)

- Animation of branches using physically based techniques [Giacomo 01, Akagi 06]
  - Fluid discretized
  - No high-level control by keyframe
- Continuous fluid flows
  - Motion paths [Wejchert 91]
  - Static hair shape modeling [Hadap 00]

Overview of Technique

- Fluid environment : continuous 3D vector field composed of singularities
  - Self-collisions or collisions with fish/anemones reduced
- Fish are associated fluid singularities

Overview of Technique

- Fluid environment : continuous 3D vector field composed of singularities
- Fish are associated fluid singularities
- Anemone tentacles represented as skeletons (chains) covered with a skin
  - Fluid forces concentrate on skeleton nodes
  - Skeleton bends towards equilibrium
  - Dynamic approach
  - Node displacement induces moments down

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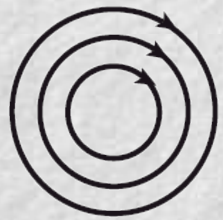
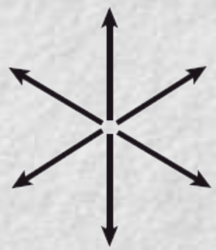
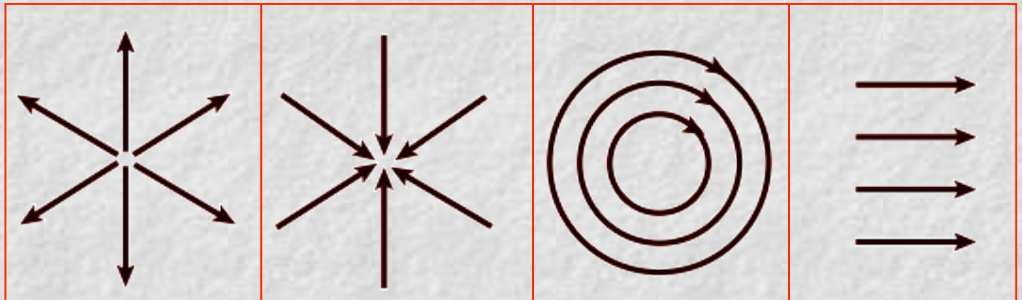




Fluid Description

- 3D vector field composed of 4 types of singularities

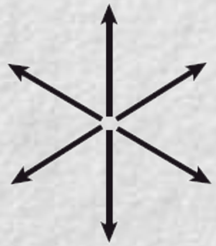
Source Hole Vortex Directional

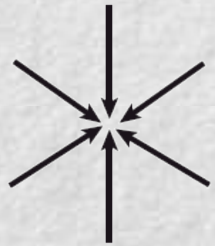


$$\mathbf{V}(\mathbf{p}) = \sum_{i=1}^{S} \mathbf{S}_i(\mathbf{p}) + \sum_{j=1}^{H} \mathbf{H}_j(\mathbf{p}) + \sum_{k=1}^{W} \mathbf{W}_k(\mathbf{p}) + \sum_{l=1}^{D} \mathbf{D}_l(\mathbf{p})$$

Singularities

- Source and Sink (Hole)
  - Intensity depends on the distance (local -- ϕ_{max} limits influence)
  - Opposite
  - To model water and fish



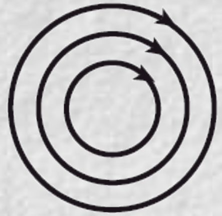


$$\mathbf{S}(\mathbf{p}) = \frac{\Phi}{\frac{\Phi}{\Phi_{max}} + d(\mathbf{p},\mathbf{C})^2} \frac{\vec{\mathbf{Cp}}}{||\vec{\mathbf{Cp}}||}$$

$$\mathbf{H}(\mathbf{p}) = -\mathbf{S}(\mathbf{p}) = -\frac{\Phi}{\frac{\Phi}{\Phi_{max}} + d(\mathbf{p},\mathbf{C})^2} \frac{\vec{\mathbf{Cp}}}{||\vec{\mathbf{Cp}}||}$$

Singularities

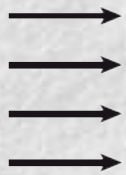
- Whirlwind (Vortex)
  - Local + rotation



- Directional Field
  - Global
  - Intensity can vary over time: sine or cosine function to obtain waves

$$\mathbf{W}(\mathbf{p}) = \pm \frac{\Phi}{\frac{\Phi}{\Phi_{max}} + d(\mathbf{p}, \mathbf{C})^2} \frac{\vec{\mathbf{Cp}} \times \vec{R}}{||\vec{\mathbf{Cp}} \times \vec{R}||}$$

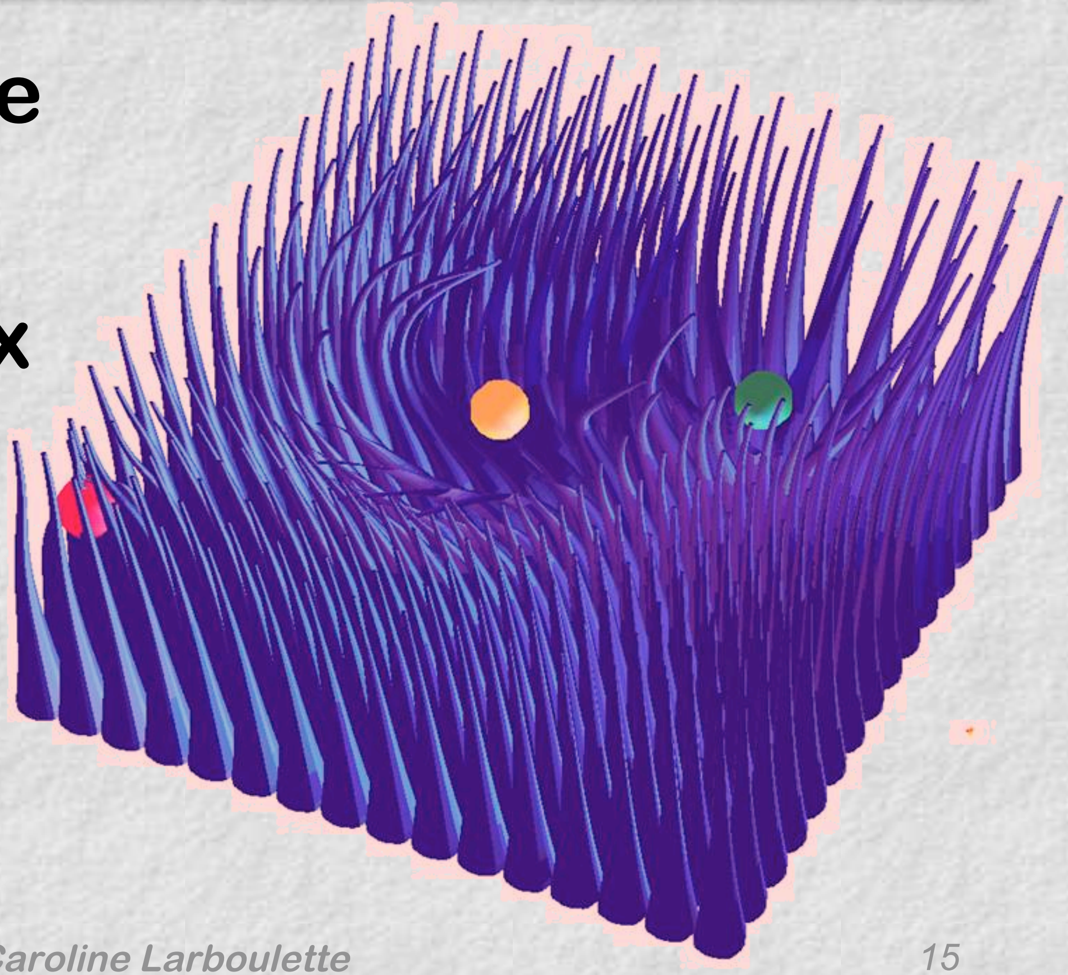
- To model currents



$$\mathbf{D}(\mathbf{p}) = \Phi(\mathbf{p}, t).\vec{v}$$

Singularities Effect

- Green: Source
- Red: Sink
- Yellow: Vortex



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- Deformation of fibers
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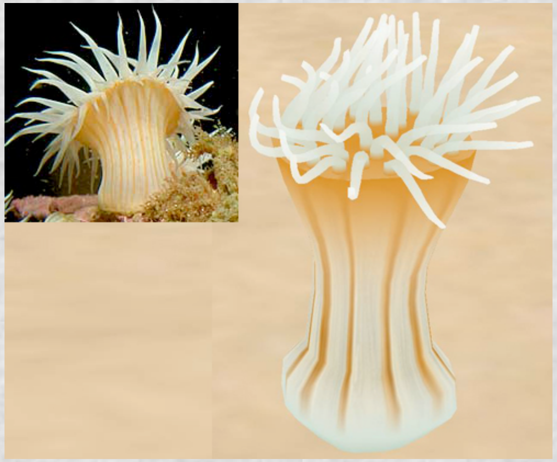
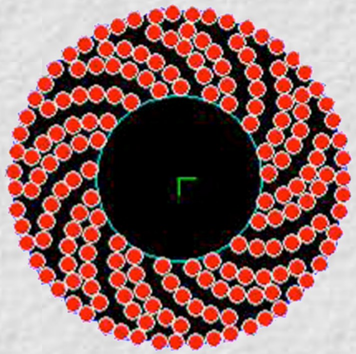
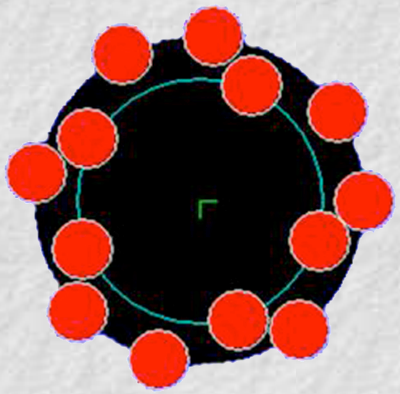
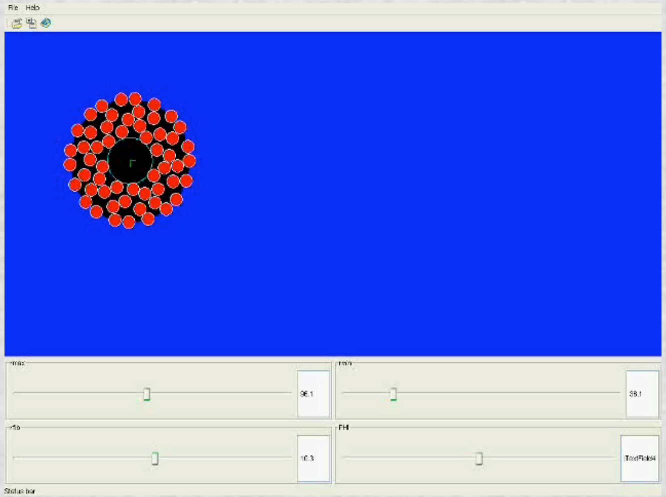


Anemone Model

- Foot : a large fiber
- Tentacles on top : many fibers arranged using a collision-based simulation of phyllotaxis [Fowler 92]

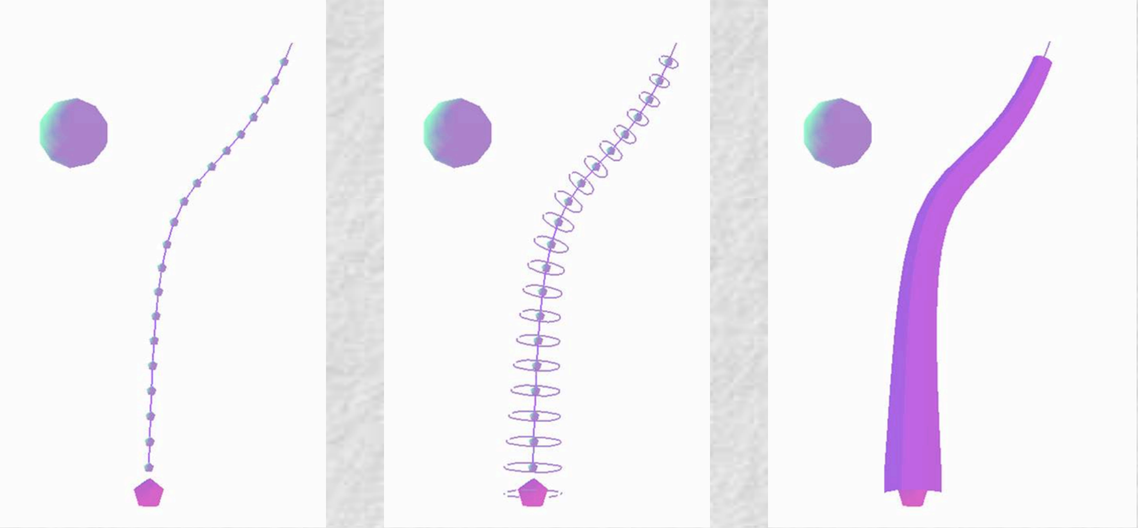






Fiber Model

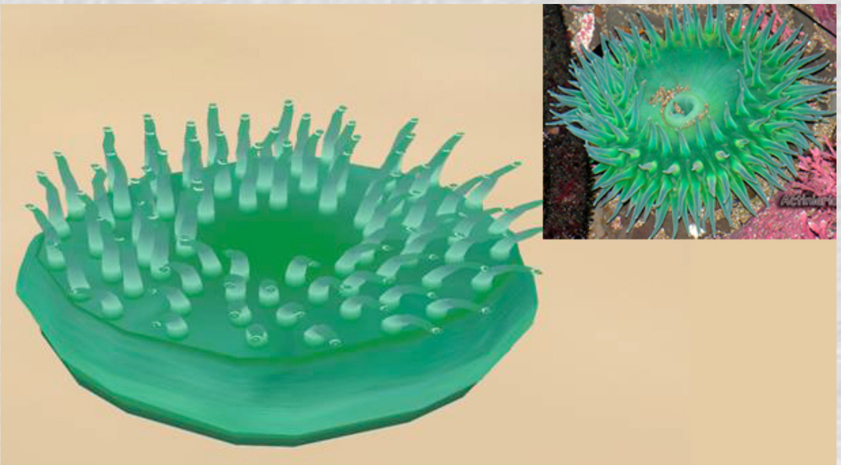
- Generalized cylinder around a skeleton
- Defined by varying radii at nodes



Textures

- Created by hand, applied automatically
- 4 species of anemones

Anthopleura xanthogrammica

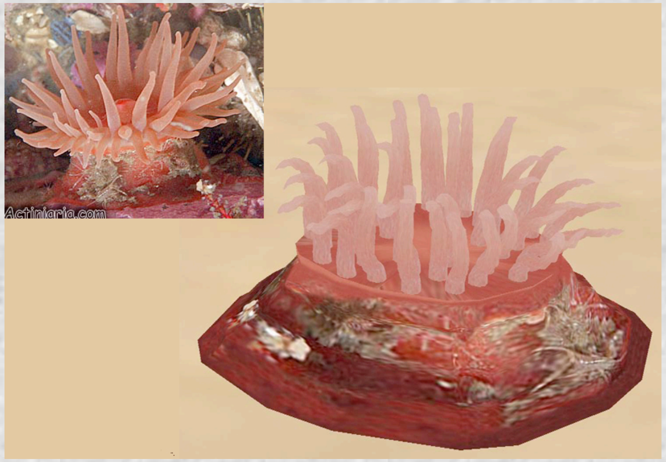


Actinia fragacea

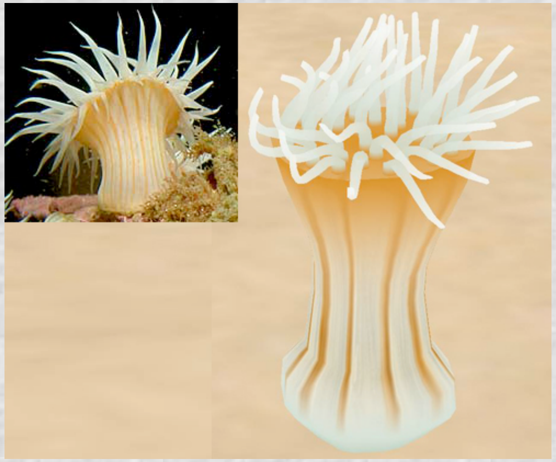
Textures

- Created by hand, applied automatically
- 4 species of anemones

Stomphia coccinea



Anthothoe chilensis



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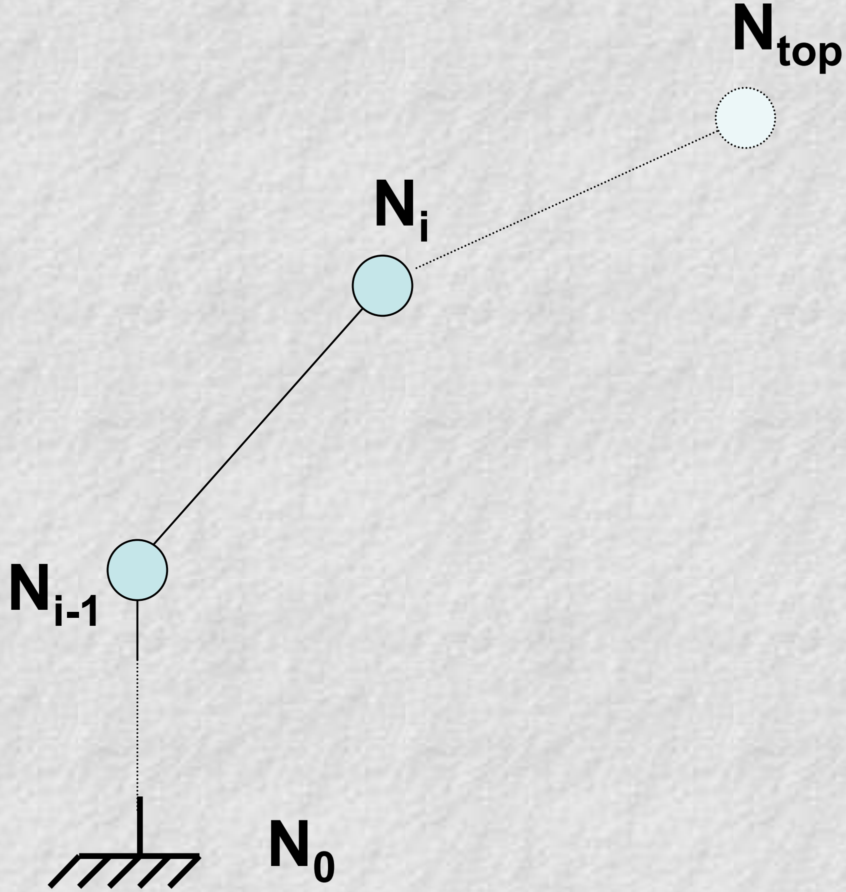
Node Chain

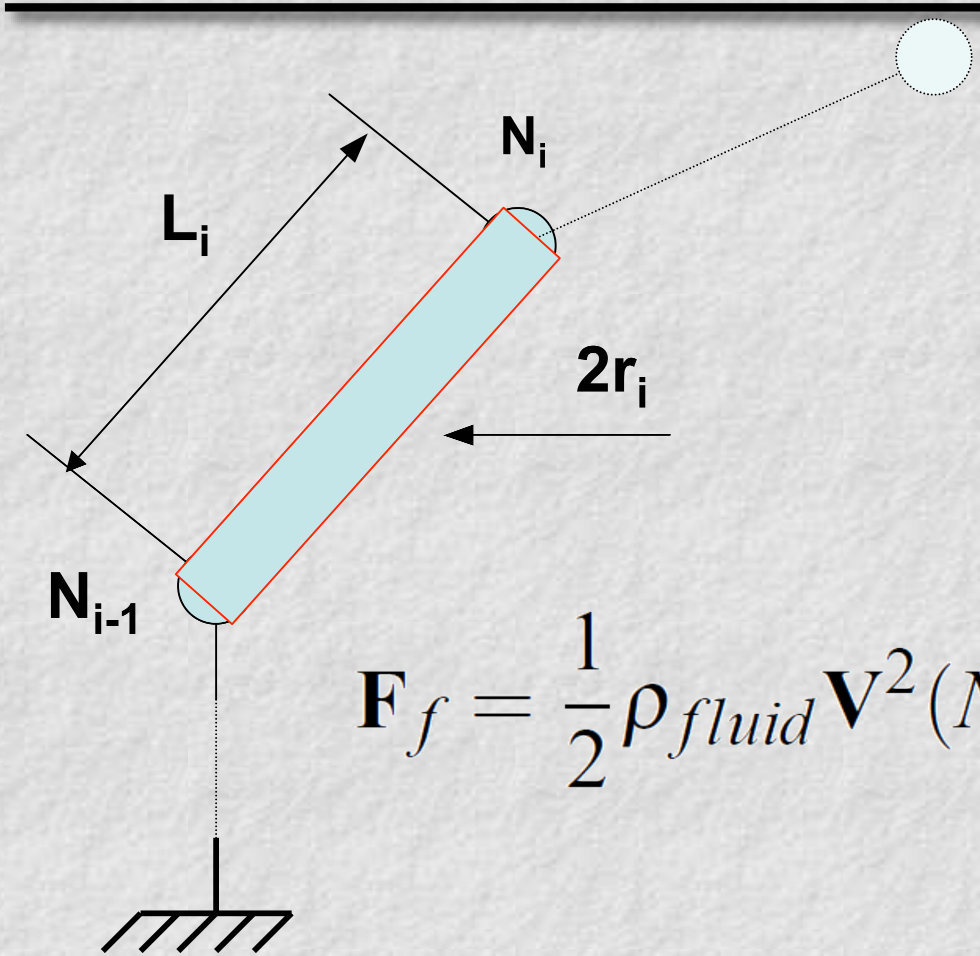
- N_0 to N_{top}
- N_0 is anchored to the foot



Deformation of the chain

- For each node
  1. Get net force from singularities
  2. Compute node displacement
  3. Transmit moment down the chain

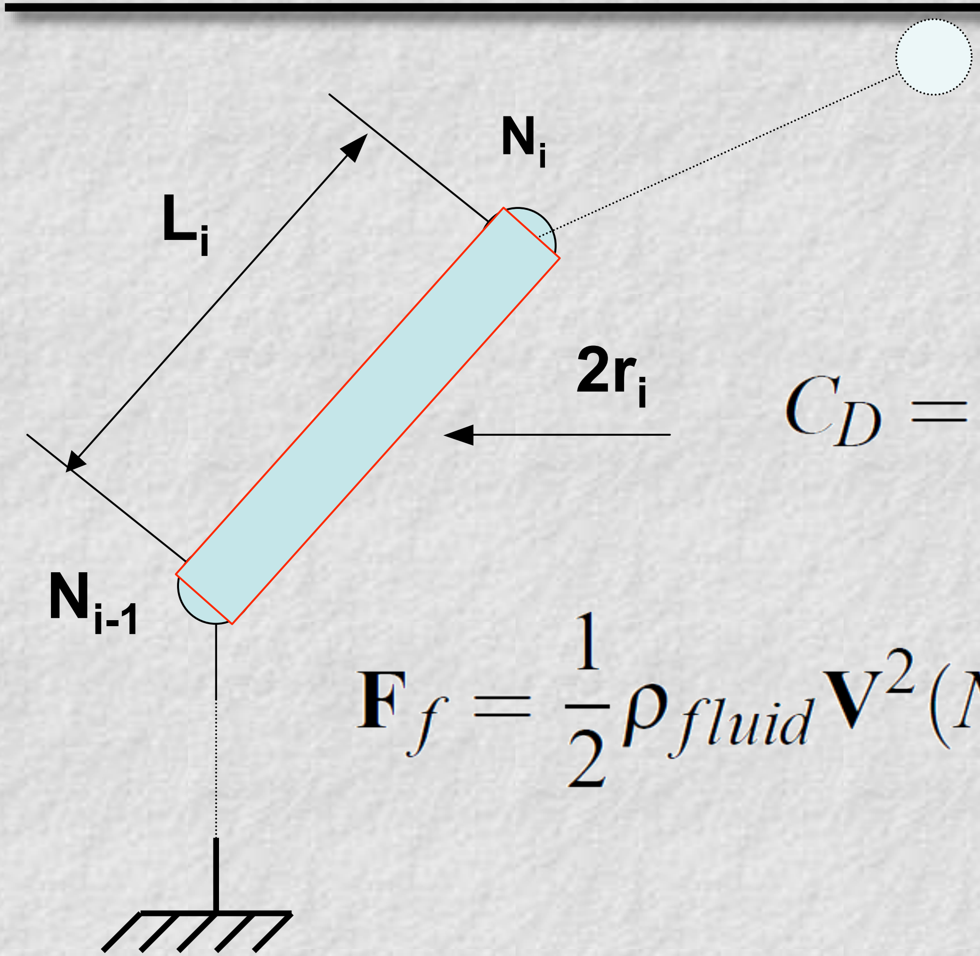
1. Net Force from Field



- Pressure Computation
- N_i: current node
- V: velocity from vector field

$$\mathbf{F}_f = \frac{1}{2}\rho_{fluid}\mathbf{V}^2(N_i)L_i 2r_i C_D \frac{\mathbf{V}(N_i)}{||\mathbf{V}(N_i)||}$$

1. Net Force from Field

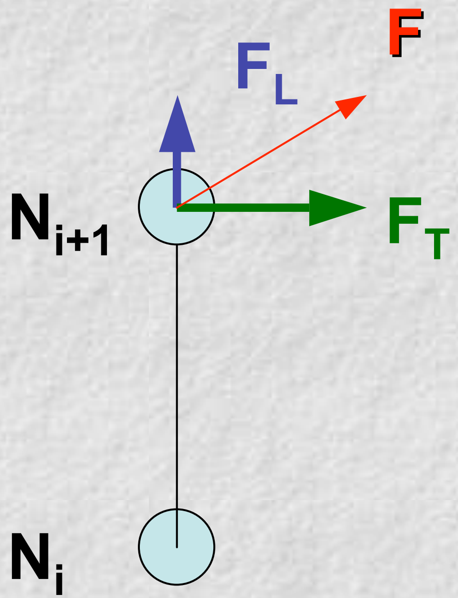


$$R_e = \frac{\rho V 2r}{\mu}$$

$$C_D = \begin{cases} 1.2 & \text{if } R_e < 5.10^5, \\ 0.5 & \text{otherwise.} \end{cases}$$

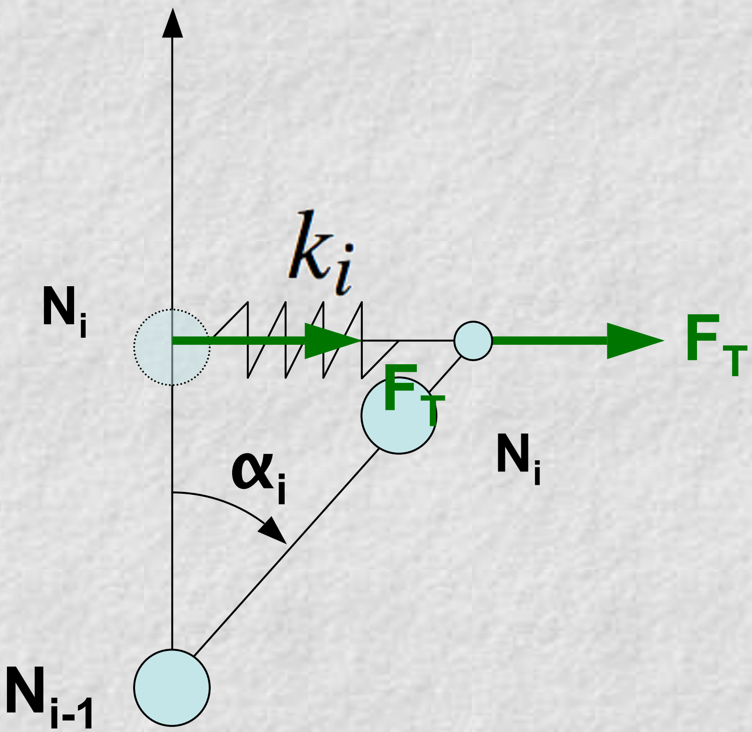
$$\mathbf{F}_f = \frac{1}{2}\rho_{fluid}\mathbf{V}^2(N_i)L_i 2r_i C_D \frac{\mathbf{V}(N_i)}{||\mathbf{V}(N_i)||}$$

Forces Analysis



- $F = F_L + F_T$
- F_L propagated to N_i
- F_T: node is displaced towards equilibrium
- Moment induced by node displacement is propagated to N_i

2. Node Displacement



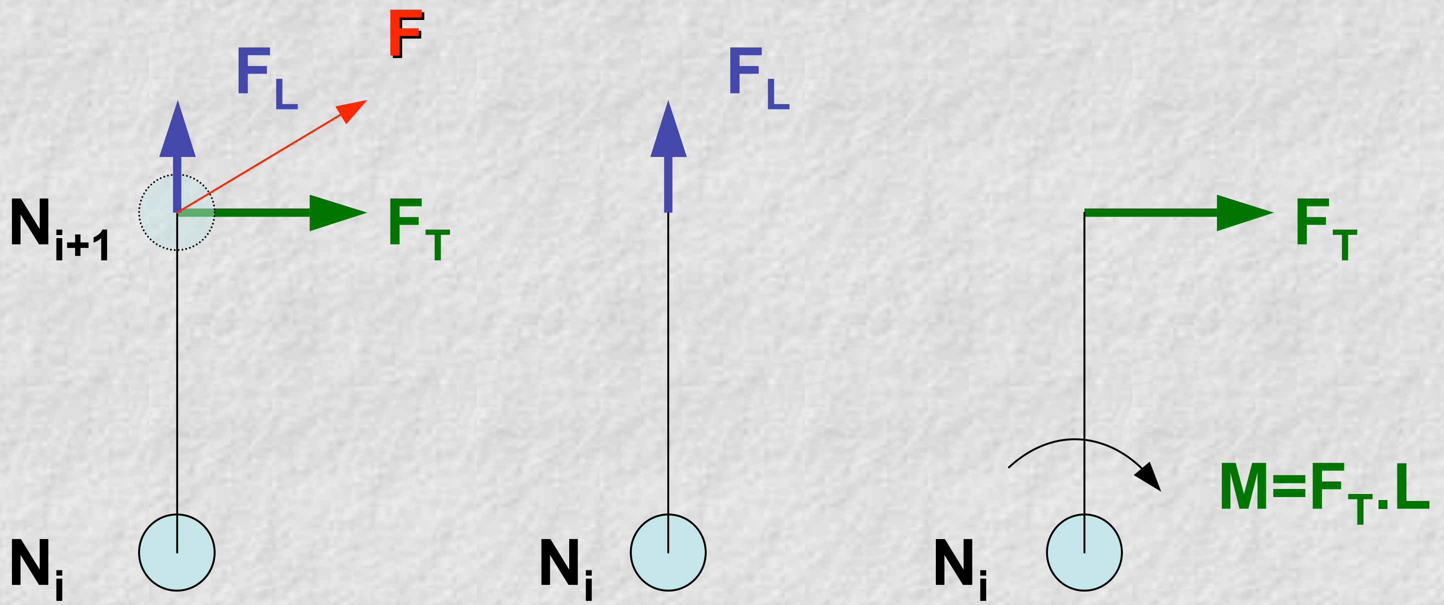
- Elastic force gives a bending angle
- k_i : stiffness at node Ni

$$k_i = {r_i}^n . K_{material}$$

- Moment generated:

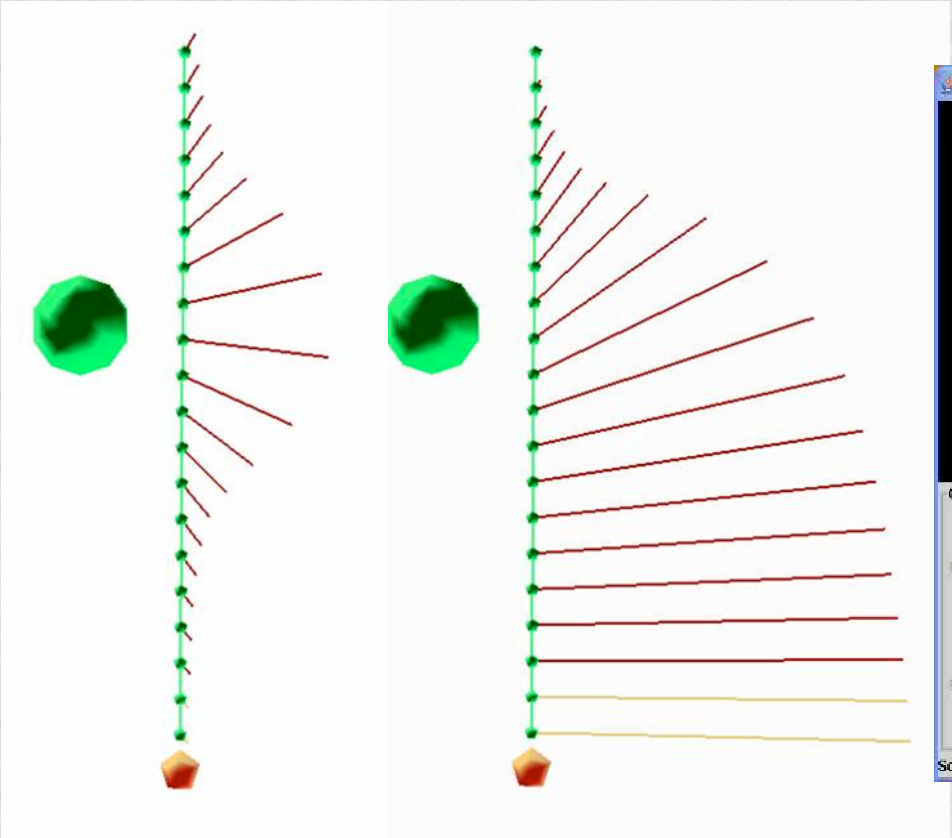
$$\mathbf{F_M}(N_{i-1}) = \frac{M(N_i)}{L_{i-1}} . \frac{N_{i-1}\vec{N}_{i-2} \times \mathbf{M}(N_i)}{||N_{i-1}\vec{N}_{i-2} \times \mathbf{M}(N_i)||}$$

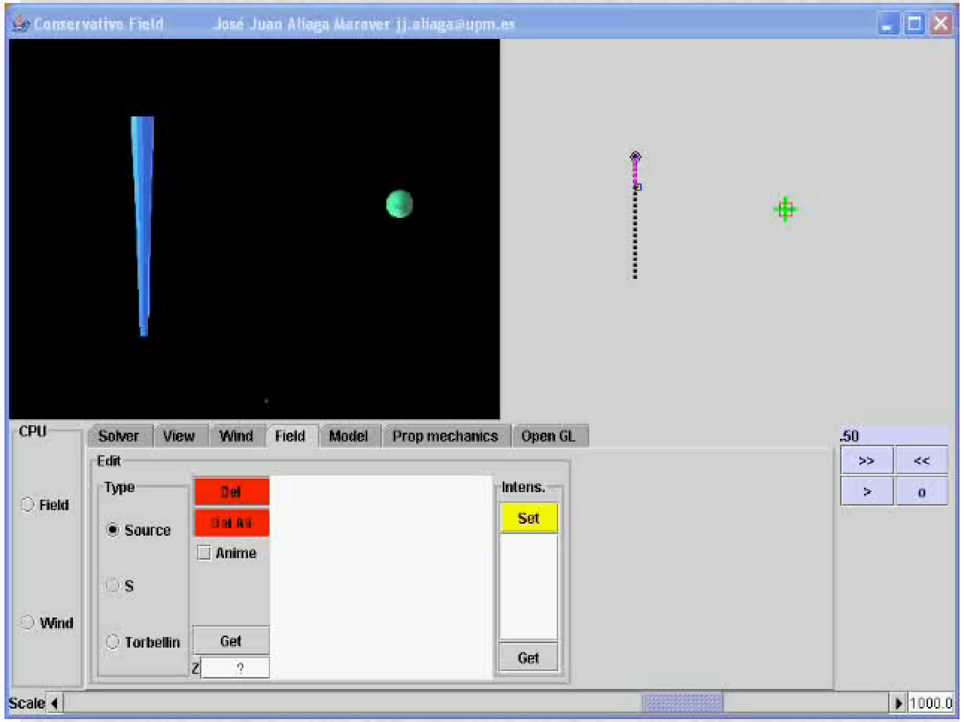
3. Propagation Moments and Forces



$$\mathbf{F}(N_i) = A.\mathbf{V}(N_i) + \mathbf{F_L}(N_{i+1}) + \mathbf{F_M}(N_i)$$

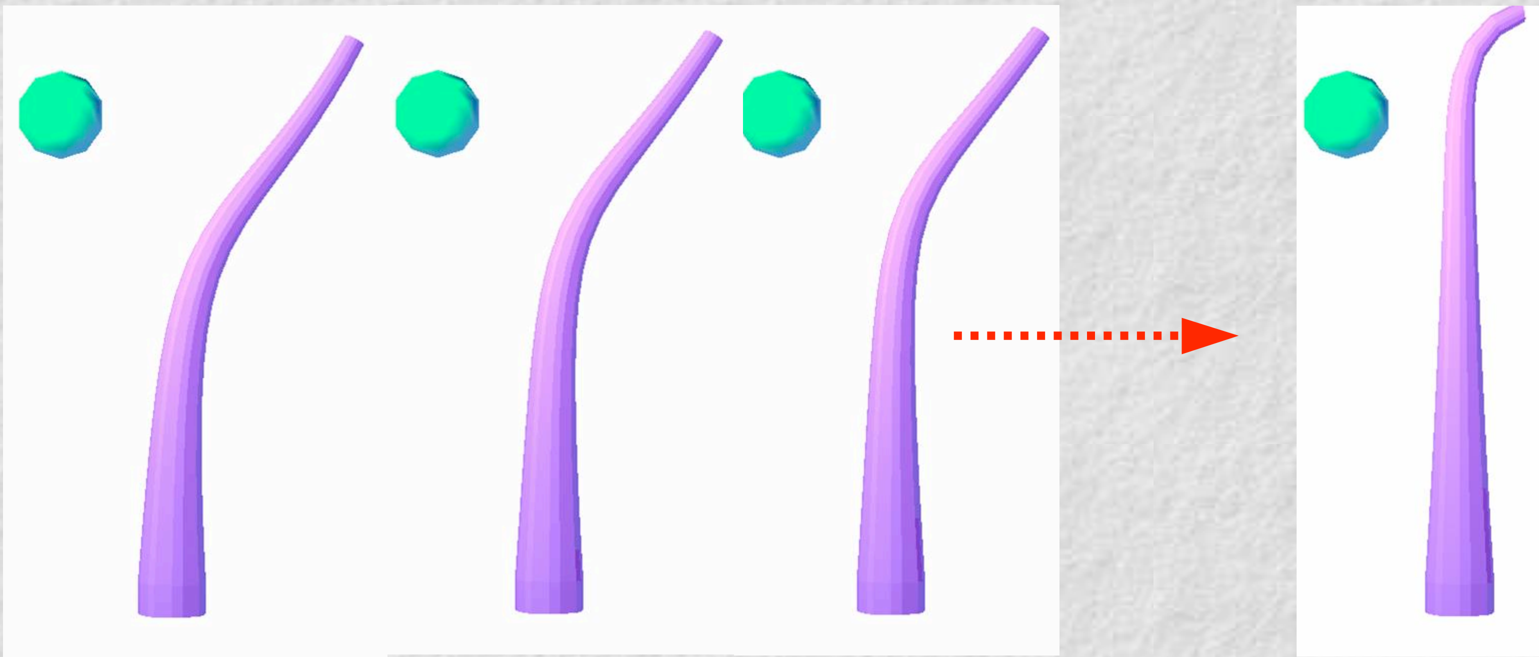
Force vs Moment





Order of Stiffness *n*

$$k_i = r_i^{\,n}.K_{material}$$



n=1 n=2 n=3 n=20

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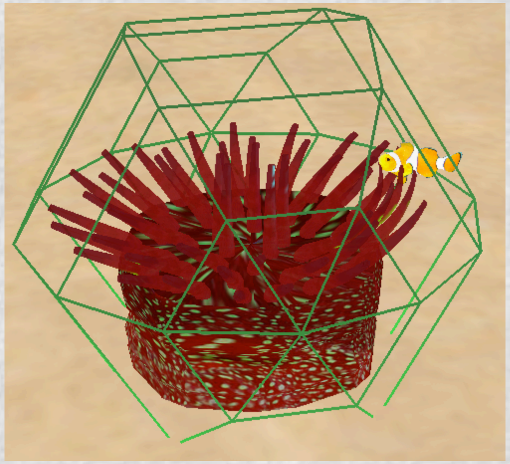
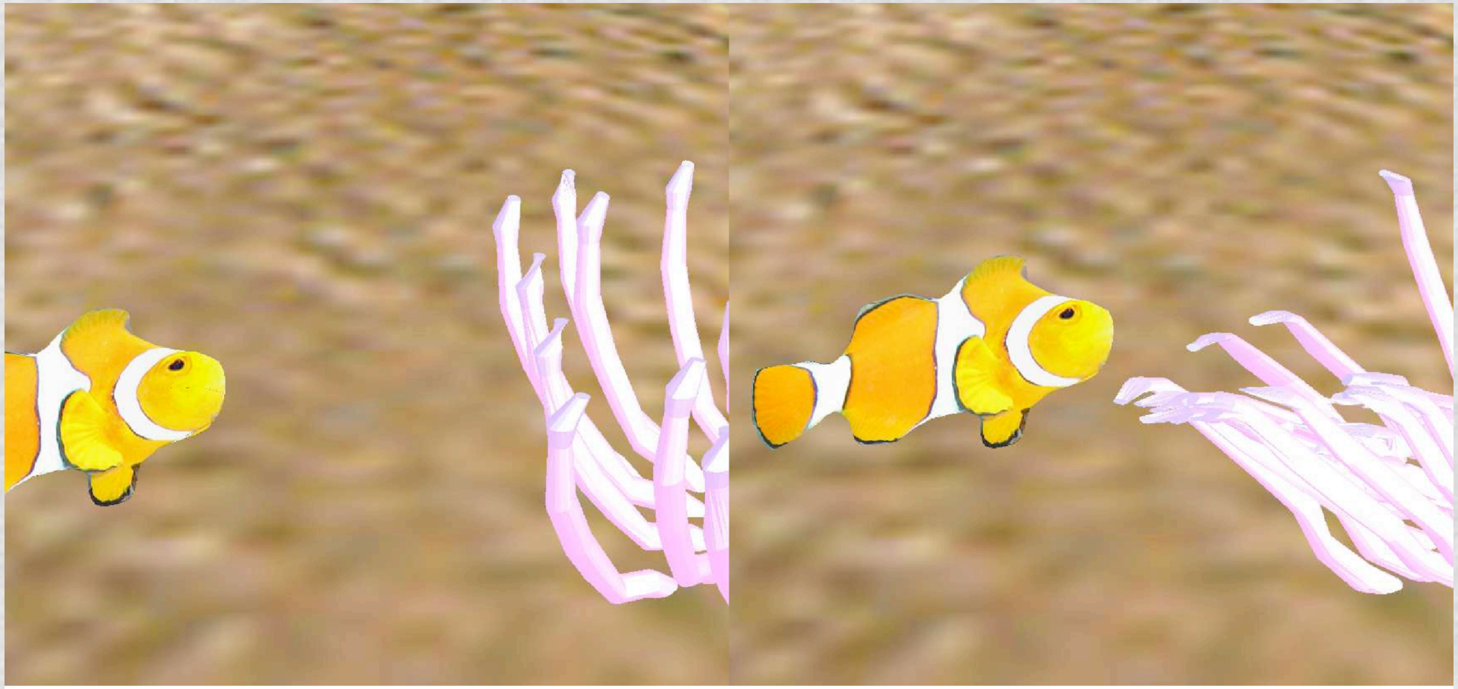


Singularity Keyframing

- Position Keyframing (singularity attached to fish)

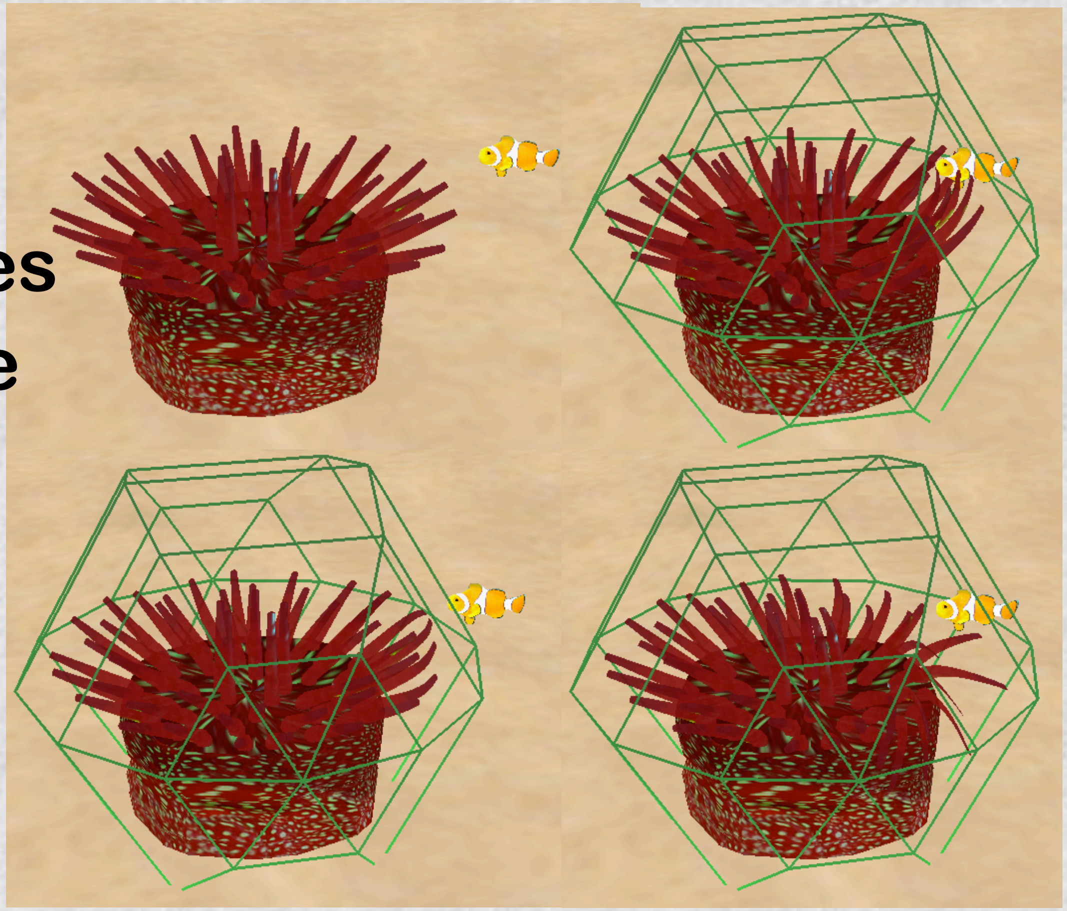
Singularity Keyframing

- Intensity Keyframing (can vary from Source to Sink)



Bounding Volumes

- BV to speed up computations
- Local singularities do not need to be evaluated



Video:

36 anemones

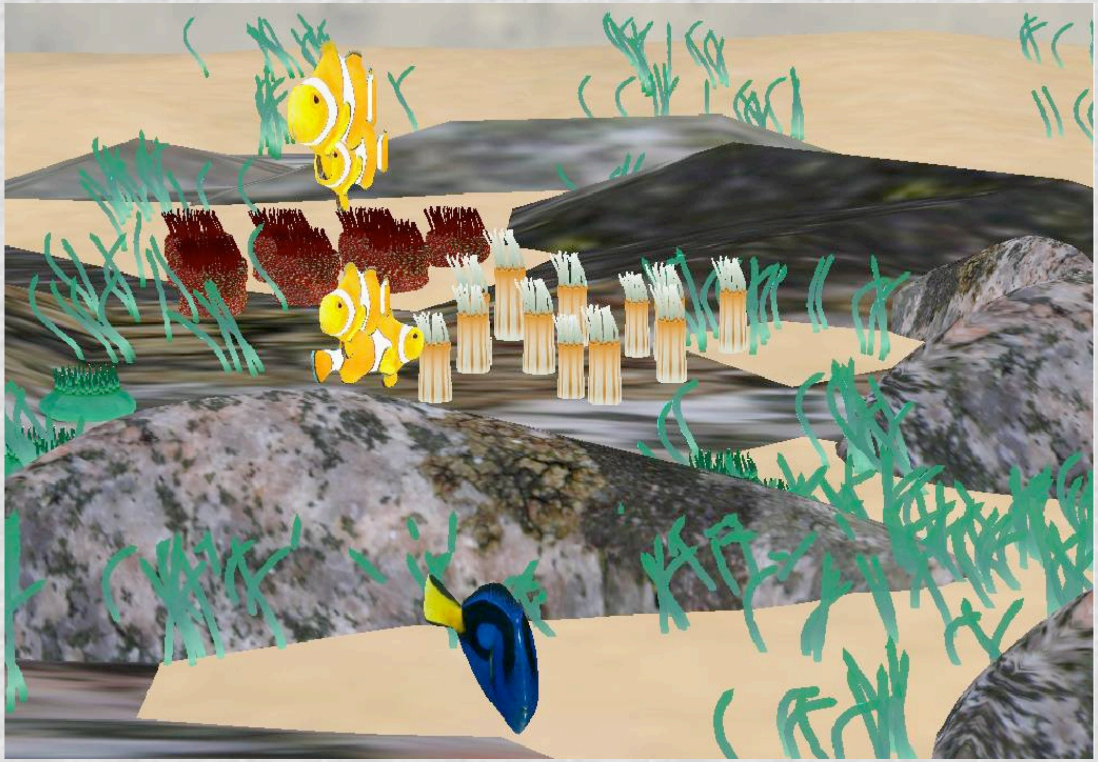
14760 nodes

17fps

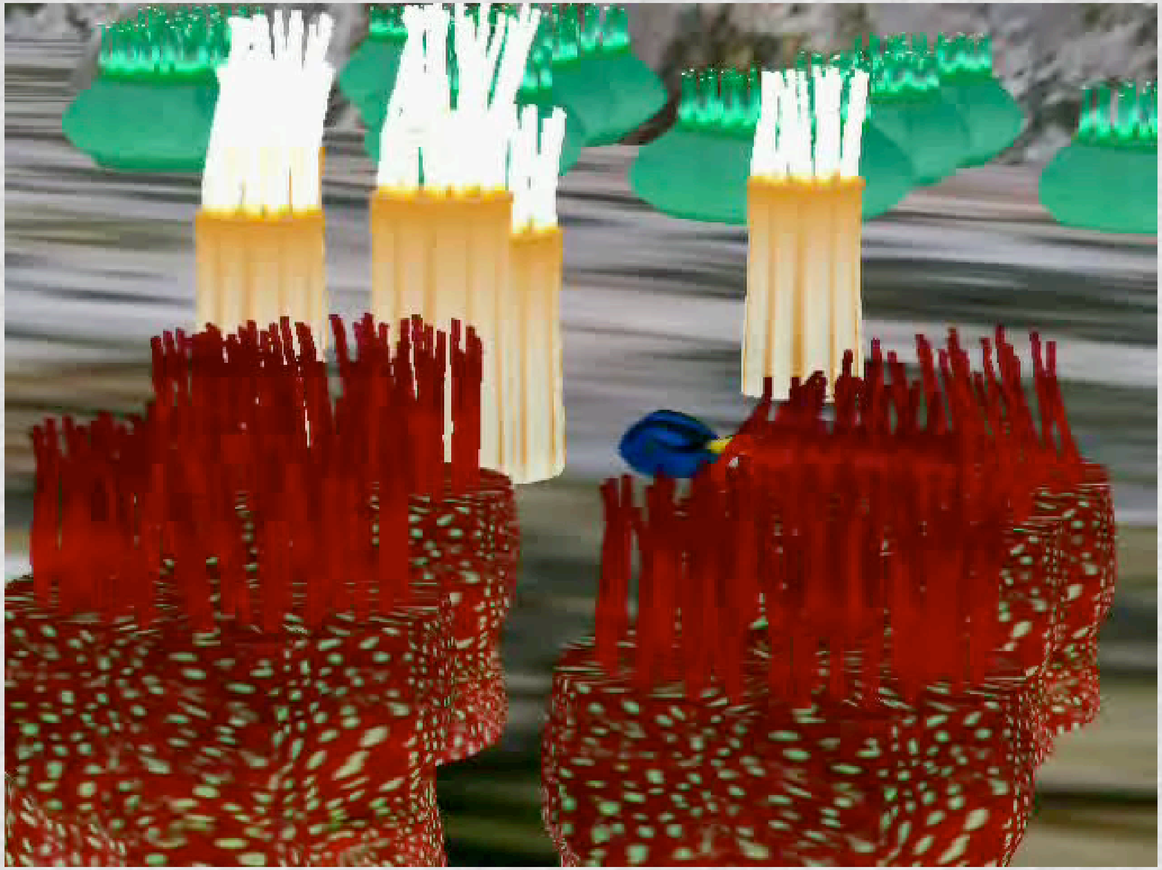
Bounding Volumes

Seascape

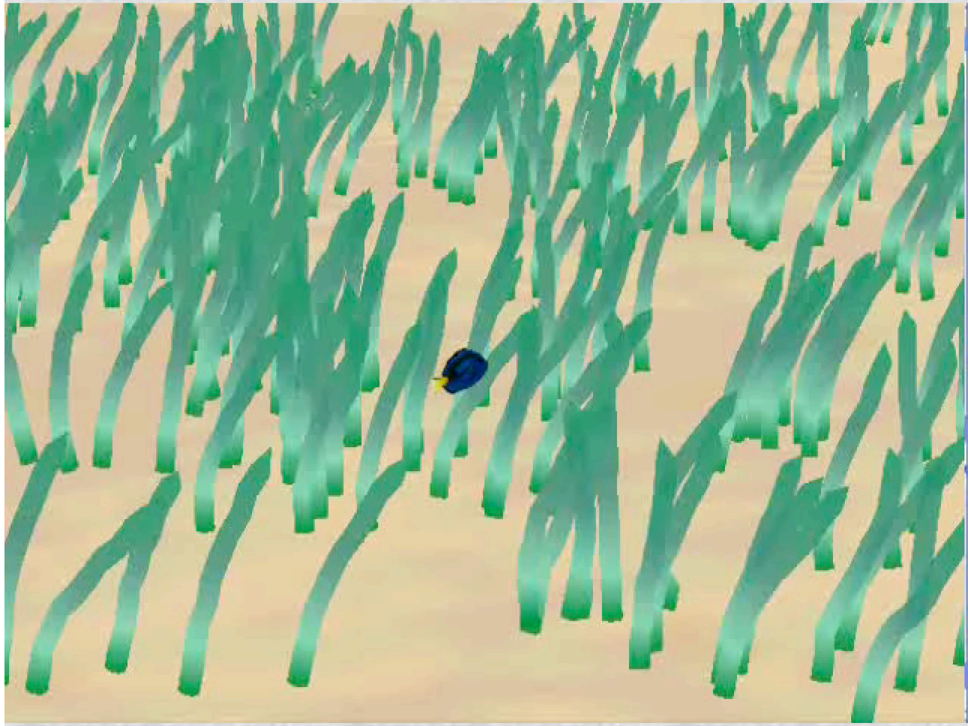
- 4 kinds of anemones
- 2 types of fish
- Seagrasses



Seascape video

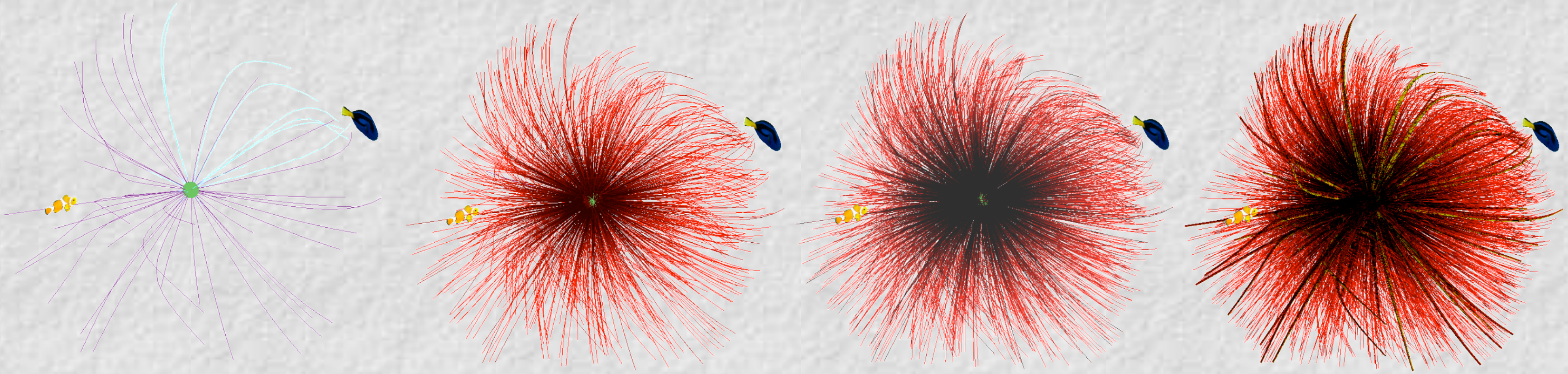


Seagrasses videos

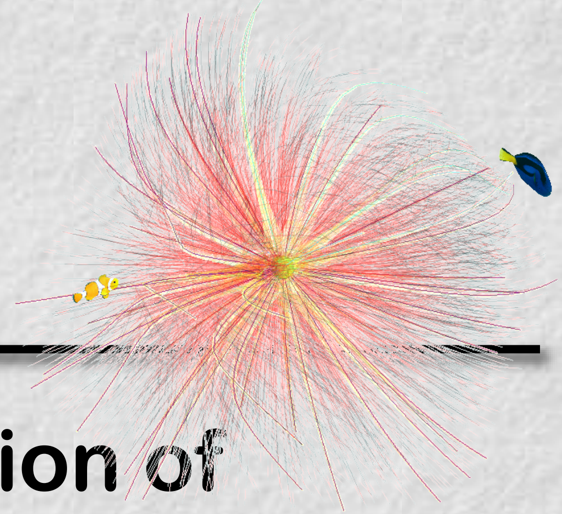


More fibers ...

- Gravity force
- Fibers interpolated



Conclusion



- Physically based animation of anemones tentacles
- Real-Time (video games)
- GPU compatible
- Collision detection reduced
- Can be used for other types of plants
- High-level keyframing (fish)

Future Work

- GPU implementation
- Improve the foot of the anemone
- Create parameters reference table for
  - Different kinds of anemones
  - Other types of plants
- Add some behavioral movement
- Perceptual study to show the impact of our simplifications
- Extend the algorithm for hair

Thanks !!! Questions ?

- Work partially supported by the Spanish Ministry of Education and Science (grant TIN2007-67188)