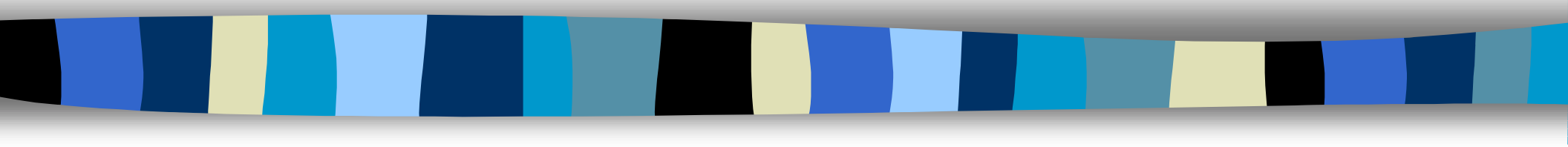
Animating Trees



Scott Peterson

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Topics

- Early Attempts
- Creating Tree Models
- Representing Trees Using Curves
- Deforming Tree Models for Animation

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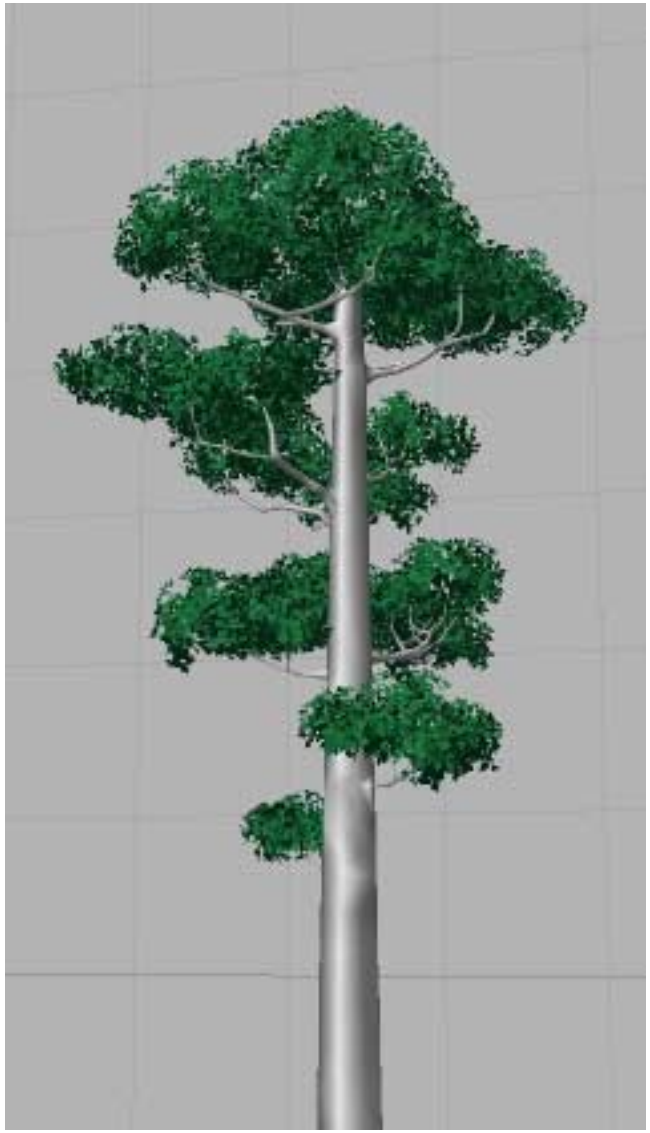
Early Tree System

- Based on Leaf clumps
  - Tree trunk, branches, and leaf clump surfaces are manually modeled
  - Tiny branchlets are scattered inside leaf clump surfaces
  - Problems
    - resembles a topiary
    - limited animation of leaves



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Early Tree Animation

- Direct Simulation of branches
  - convert branch segments into particles and connect together using length/torsion springs
  - Problems:
    - stiff branches explode into chaos
    - extra simulation step required in every shot before rendering
    - subtle motion is not worth the cost

Creating Trees

- How to apply rules to a recursive structure
  - Level-based approach
  - “Creation and Rendering of Realistic Trees,” Jason Webber and Joseph Penn, Siggraph ‘95 Proceedings
- Add Branches to hand-modeled trunk
- Prune resulting tree

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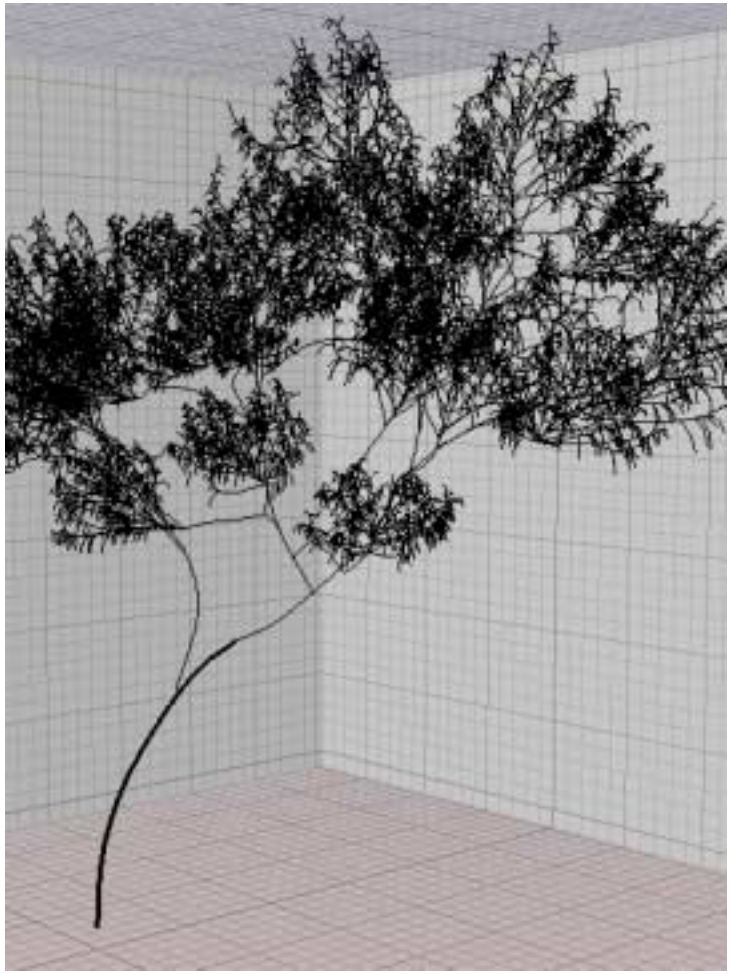
Representing Trees

- Curves
  - Can be adapted to represent tubes
  - not limited to branches at discreet points
  - compact data structure
  - flexible file format



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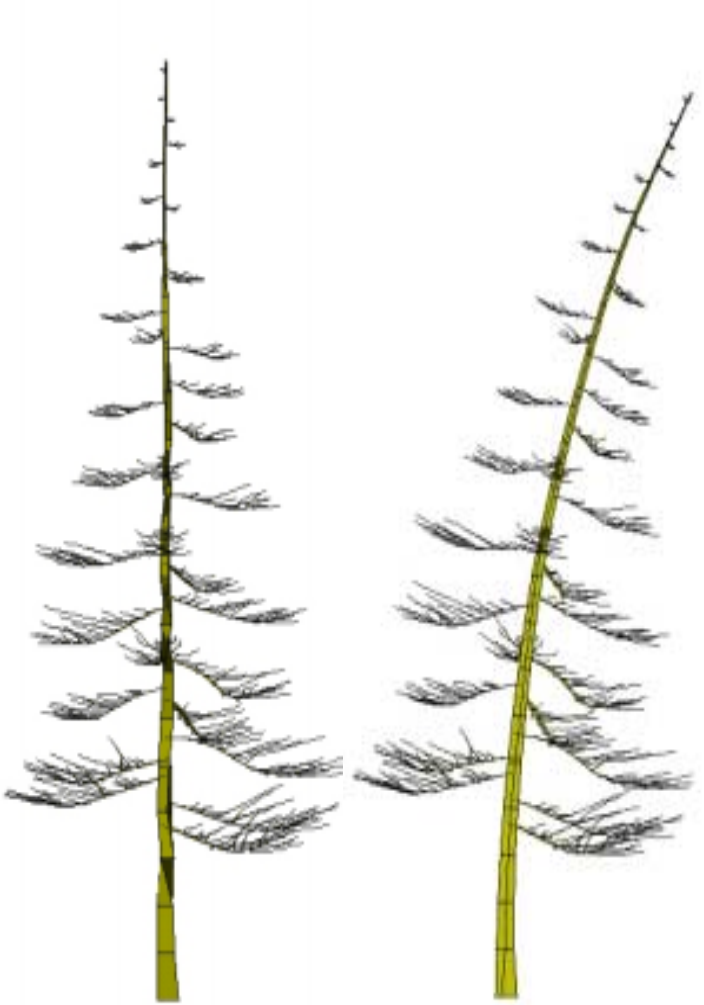
Branch Hierarchy

- Each branch except for the trunk has a parent branch
- Connectivity is the parameter value along the parent curve where the child curve begins



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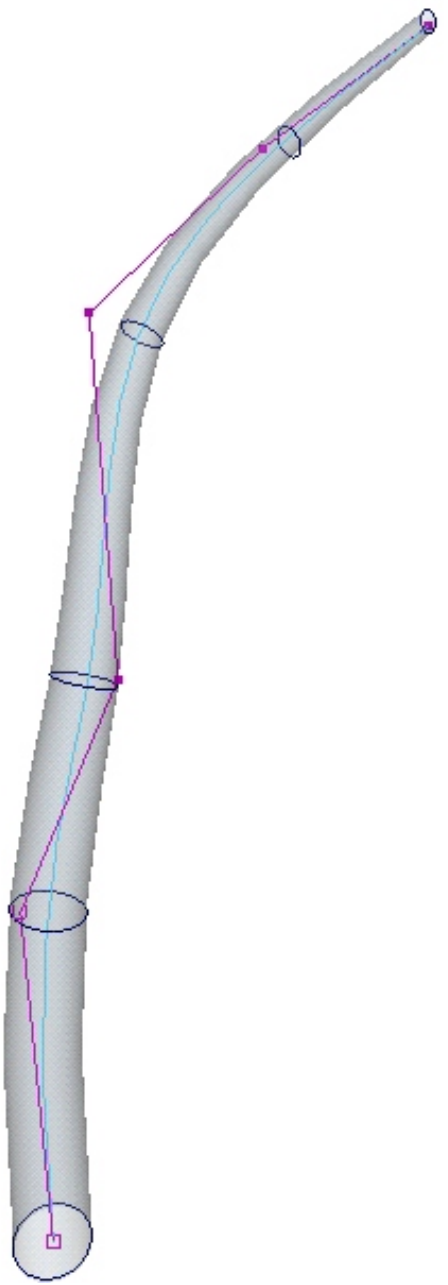
Tree Geometry: tubes

- A Tube is created by extruding a circle through a curve
  - radius is an extra attribute of each control vertex
- Tubes that are connected by endpoints are stitched together in order to hide seams



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Tree Geometry: large fillets

- Relaxing the union of branch shapes

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Tree Geometry: Leaves

- Instanced procedurally
- Based on tree-specific parameters
  - examples
    - angle of deflection
    - overall scale, random scale variation, scale as it relates to length of branch
    - rotation about parent branch

Animating Trees

- Force Fields
  - gentle breeze: simulation
  - character interaction: keyframe animation or procedural animation

Deforming a Branch

- Force sampled at tip of branch
- Bend Factor
  - same direction as force
  - increases over length of branch

$$\mathbf{b}_i = \mathbf{b} \cdot \left(\frac{i}{n-1} \right)^2$$

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Deforming a Branch: definitions

- Definitions
  - b : vector representing the bend factor applied to an entire curve
  - b_i : vector representing the bend factor applied to a control vertex
  - n : number of control points
  - c_i : vector describing the position of a control point in a curve
  - c_i' : vector describing the position of c_i after it has been deformed

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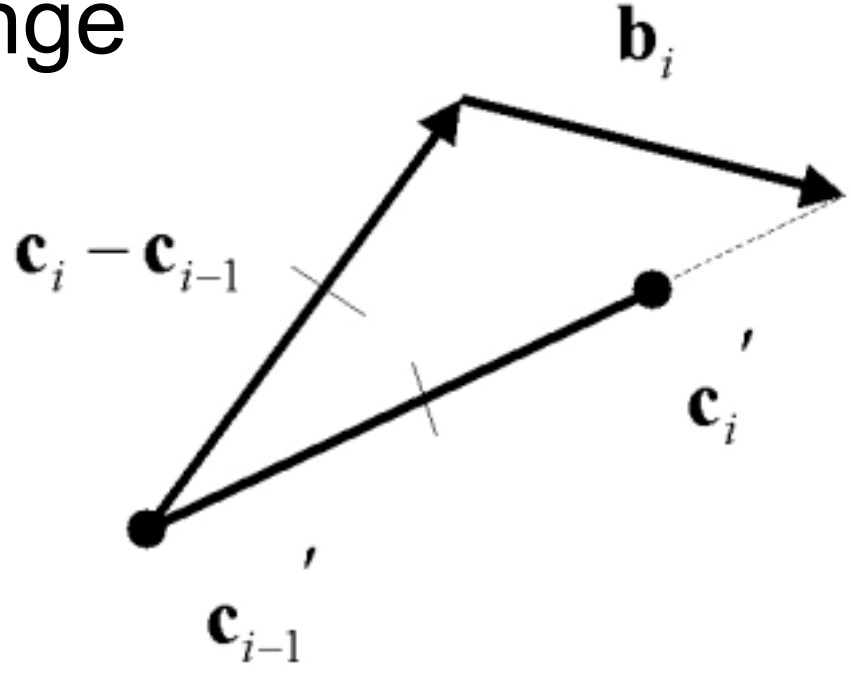
Deforming a Branch: Applying Bend Factor

- Preserve distances between control vertices (only change direction)



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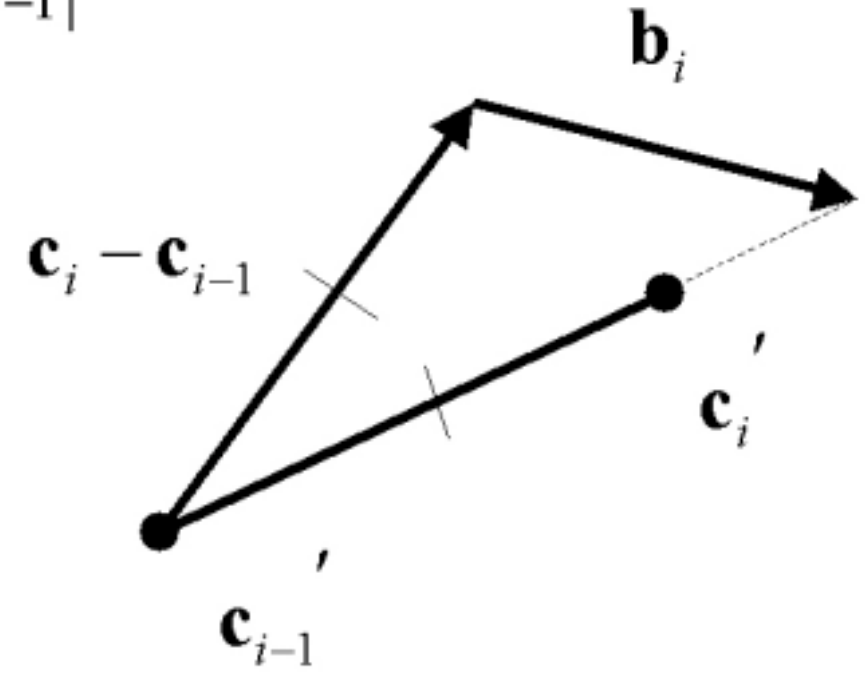
Deforming a Branch: equation

$$\mathbf{c}_i' = \mathbf{c}_{i-1}' + \frac{(\mathbf{c}_i - \mathbf{c}_{i-1}) + \mathbf{b}_i}{|\mathbf{c}_i - \mathbf{c}_{i-1}|}$$



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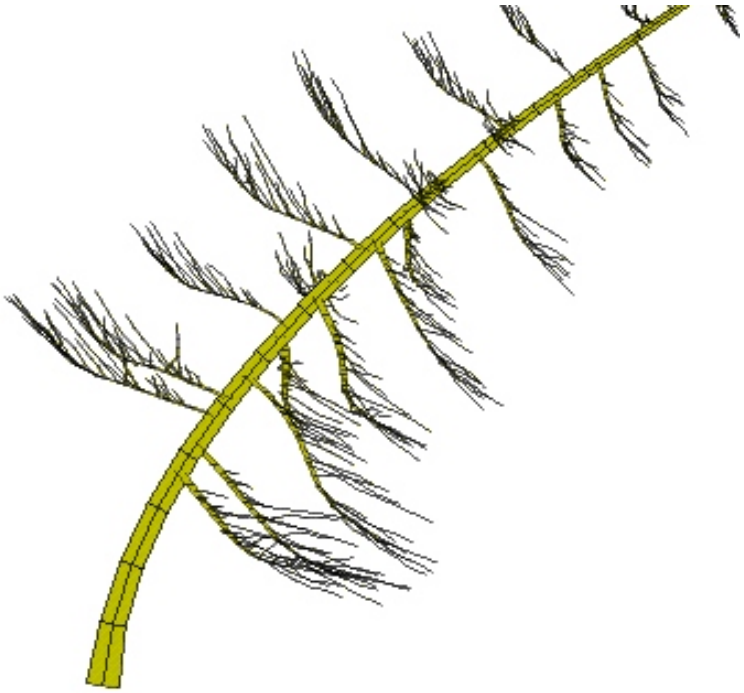
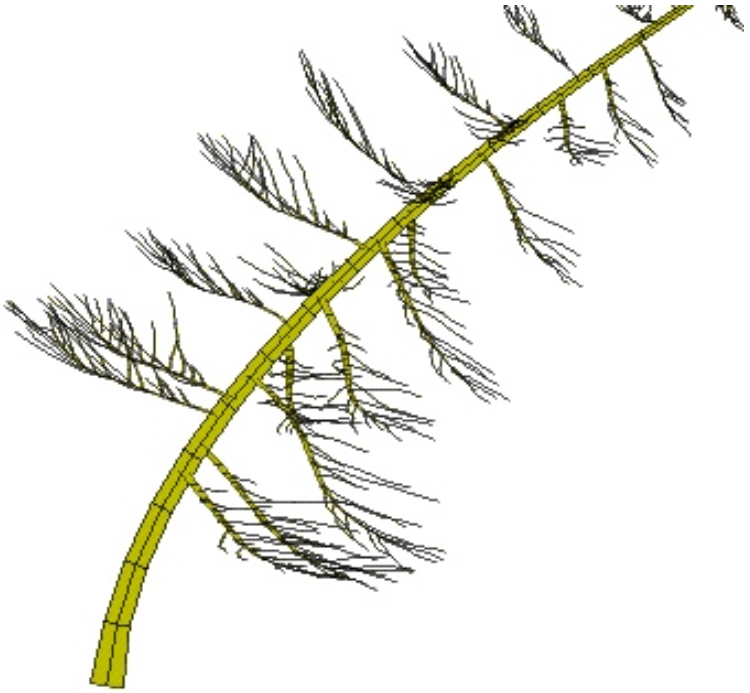
Deforming a Tree

- Maintain branch structure
- Accumulate rotations
  - a bent trunk affects direction of highest-level branches
  - derive a transformation hierarchy

Accumulating Rotations

- Accumulation vs. No Accumulation





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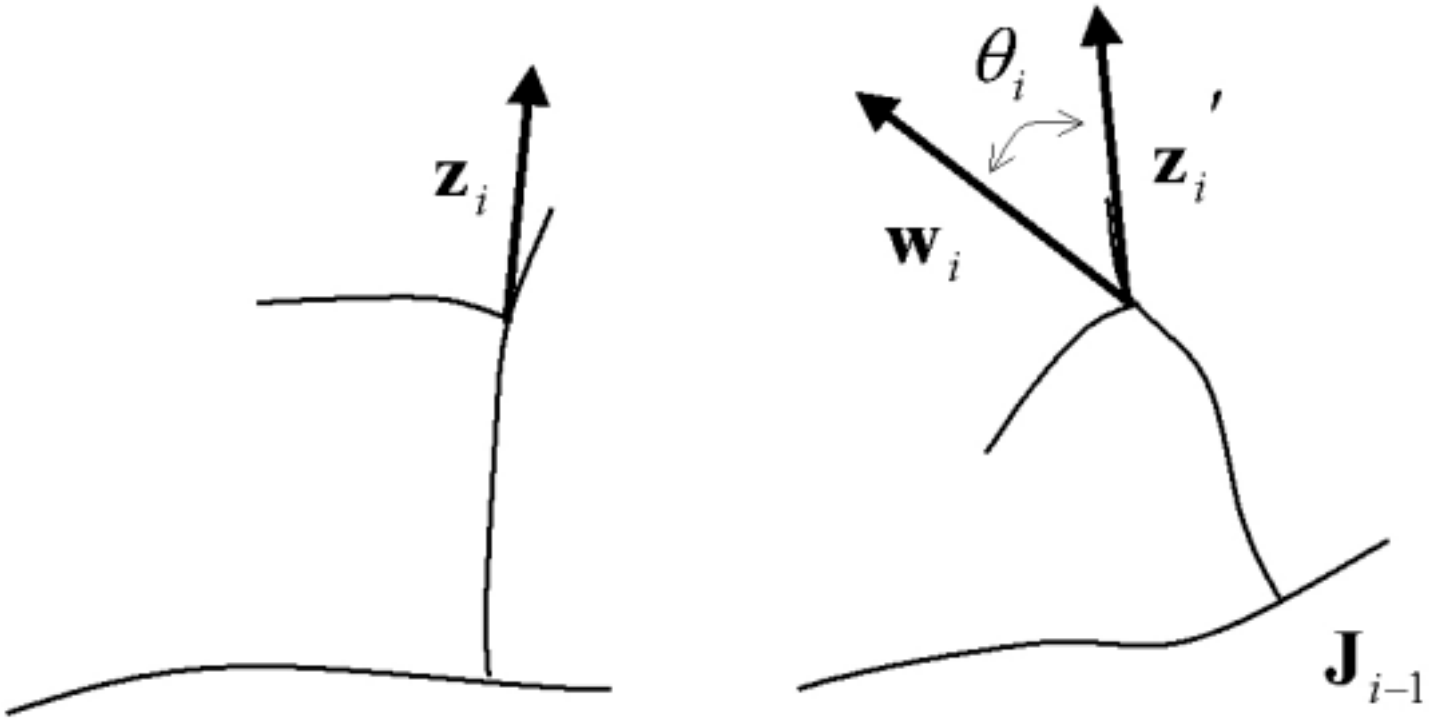
Branch Rotation Matrix

- Branch hierarchy before and after deformation



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Branch Rotation Matrix: definitions

- Variables expressed in terms of level i
  - J_i : 3x3 orientation matrix
  - z_i : tangent of parent curve
  - z_i' : z_i transformed by parent branch orientation

$$\mathbf{z}_i' = \mathbf{J}_{i-1}\mathbf{z}_i$$

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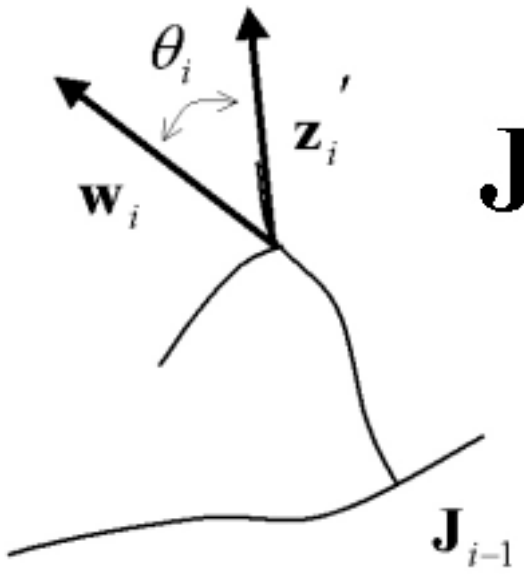
Branch Rotation Matrix: equation

- R(*v*, *a*) : Function that creates a 3x3 rotation matrix from '*a*' radians about vector '*v*'



$$\mathbf{J}_i = \mathbf{J}_{i-1}\,\mathrm{R}(\mathbf{z}_i' \times \mathbf{w}_i, \theta_i)$$

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Conclusions

- A compact tree file format
  - Separate tools for modeling, animating, and rendering trees
  - network i/o is minimized when deforming and rendering thousands of trees
- Apply force as bend-factor, no direct simulation
- Accumulate rotations when deforming a tree

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Thank-You

- Jonathan Gibbs - tree tesselation expert
- Marty Usiak - birch tree expert
- Ken Bielenberg - cg supervisor

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