Art-Based Rendering of Fur, Grass, and Trees

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SIGGRAPH 99

Michael Batchelder

Outline

- Introduction
  - Motivation
  - Dr. Seuss and others
- Background Work
- Approach
- Results
- Related Work
- Conclusion

Dr. Seuss – Self-Portrait of an Artist Worrying about His Next Book

Introduction

- Motivation
  - Would like to simulate real world objects of large complexity, such as grass or trees.
  - Alternate (NPR) styles (ala Dr. Seuss).
  - Should be fast enough for real-time animation.
  - Would like some level of temporal coherence in animation.

Trees

Cover Art for The Lorax – Dr. Seuss

Fur/Hair

Hop on Pop – Dr. Seuss

Curt Kirkwood www.curtkirkwood.com

Dr. Seuss – The Lorax

Outline

- Introduction
- Background Work
  - Particle Systems, L-Systems, and Graftals
  - Orientable textures
- Approach
- Results
- Related Work
- Conclusion

Background Work

- William Reeves “A Technique for Modeling a Class of Fuzzy Objects” - 1983
  - Used particle systems used to represent explosions, fireworks, clouds, and water
  - Over time, particles can be added, removed, and moved to represent a dynamic 3D model.
  - Motion-blurred to deal with temporal coherence

Expanding Wall of Fire - Reeves

Background Work

- Alvy Ray Smith “Plants, Fractals, and Formal Languages” - 1984
  - Used particle systems combined with recursively defined L-Systems that he called “graftals”.
  - Flowering Plants are Graftals, Grasses are particle systems

White Sands – Alvy Ray Smith

Background Work

- L-Systems introduced by Lindenmayer in 1968
  - Parallel rewriting grammars.
  - Bracketed L-Systems allow for branches to be attached at points within the sequence, like branches off a trunk (or off other branches).
    - Extension: Notion of left and right
  - Similar to Fractals.

Background Work

- Example:
  - Alphabet: { 0, 1, [,] }   note: (,)
  - Productions:
    { 0 -> 1[0]1[0]0, 1 -> 11,] ->], [-> [}
  - Start: 0

Alvy Ray Smith – Plants, Fractals, and Formal Languages

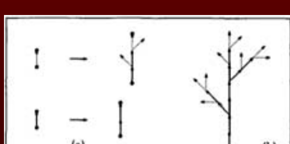


Figure FREETREE. (a) Production rules. (b) Generation n = 2.

Background Work

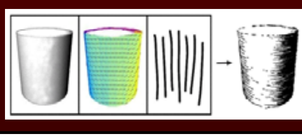
- Cartoon Tree – Kowalski calls it “direct precursor to the work in this paper”.

Cartoon Tree produced from Example Grammar

Alvy Ray Smith – Plants, Fractals, and Formal Languages

Background Work

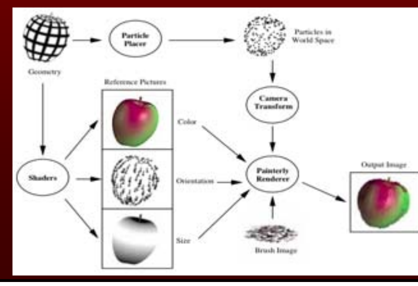
- Badler and Glassner generalize idea in “3D Object Modelling”:
  - Graftals create surfaces via an implicit model that produces data when requested.
- Salisbury, et al's “Orientable Textures for Image-Based Pen-and-Ink Illustration”
  - “difference image” stroke placement algorithm.



Applying strokes with a direction field and tone image Salisbury, et al.

Background Work

- Meier's “Painterly Rendering for Animation”
  - Represented strokes as particles, sorted by depth, rendered back to front.



Outline

- Introduction
- Background Work
- Approach
  - Procedural textures (Graftals!)
  - Reference images & Difference Image Algorithm
- Results
- Related Work
- Conclusion

Approach

- Stroke-based textures are implemented within a general system for rendering polyhedral models using OpenGL
  - Models are divided into surface regions (patches) which are assigned procedural textures.
  - Textures can be smooth-shaded, wireframe, hatching, dithering, etc.
  - Color and ID references images maintained for use by procedures

Approach

- Color reference image.
  - Procedural textures are asked to render into their patches in some appropriate way, depending on how the texture will use the image.
    - For example: graftals use color image in special way to decide where to place tufts of fur, grass, or leaves.

Approach

- ID reference image.
  - Triangles (or edges) are rendered with unique color that identifies that triangle (or edge).
  - Pixels containing the ID of a triangle have their location stored in a list attached to the patch they are in.
  - Later, procedural textures have acces to these pixels in main rendering loop.
    - Example: the dithering texture just runs the Floyd-Steinberg algorithm on the patch's pixels

Approach

- Graftals: specialized textures
  - Graftals must be placed with controlled screen-space density to match the required aesthetics of the texture.
  - Graftals also need to “stick” to surfaces to provide interframe coherence.
  - Difference Image Algorithm of Salisbury, et al used to place graftals.

Approach

- Difference Image Algorithm:
  - In Salisbury, et al, DIA used to control density of hatching strokes to match gray tones of target image.
    - For each stroke, a blurred image of it is subtracted from the difference image.
    - Next stroke is placed by searching for the pixel “most in need” of darkening.
    - Density of strokes conveys gray tones of original image

Approach

- Graftals with DIA:
  - Texture draws it's patch into the color ref. Image so darker tones correspond to areas requiring more graftals.
  - Example: reference image drawn darker at silhouettes and, optionally, explicitly darkened by user in certain regions. (feet)

Furry Creature – Kowalski, et al

Approach

- Placing Graftals on the 3D Surfaces:
  - In first frame, use DIA to find graftal positions and convert 2D screen positions to 3D positions on model surfaces using ID reference image to find the edge / triangle the graftal belongs to.
  - In each successive frame, first try to place graftals from previous frame.
  - After previous graftals are accepted/rejected, execute DIA to place extra graftals as needed.

Approach

- Why would the previous frame's graftals be rejected?
  - It may not be visible (occluded, or off screen)
  - Insignificant desire
    - Scene has been zoomed out so too many graftals making for too dense a patch
    - Scene has been rotated/transformed such that graftal is no longer near the silhouette

Approach

- How to blur difference image?
  - Represent graftals as dots centered at it's pixel
  - Dots are gaussian-blurred
  - Dot size is proportional to graftal's “volume” - the amount of screen-space area it takes up
  - Dots represent “lack of desire” - that is, the greater the number of graftals you have, the less desire there is for more
  - What happens when the scene is zoomed in/out?

Approach

- Scaling
  - Convert object length L to screen space measurement s.
  - Choose scale factor r to multiply L by.
  - Desired screen space is d with volume v_0.
  - Kowalski chose weighted r = w (d / s) + (1 – w) where w = 0.25 to moderate degree of scaling.
  - So volume in each frame is v = v_0(r s / d)^2

Approach

- Gaussian Blur
  - The value in the desire image at the graftals (visible) screen position x_0 is d_0 and let v > 0 be the volume.
  - Find a 2D Gaussian function g such that:
  - This is

$$g(\mathbf{0}) = d_0 \quad \text{and} \quad \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} g(\mathbf{x})\, dx dy = v.$$

$$g(\mathbf{x}) = d_0 e^{-\pi d_0 |\mathbf{x}|^2 / v}$$

Approach

- Gaussian Blur $g(\mathbf{x}) = d_0 e^{-\pi d_0 |\mathbf{x}|^2 / v}$
  - This blur drops off to a very small amount outside a certain radius so take m to be the smallest value representable in the 8 bits used to store desire and find a maximum radius to subtract desire from:

$$(v \log(2d_0/m)/(\pi d_0))^{1/2}$$

Approach

- Graftal Detail
  - A graftal can only subtract as much desire as is available at a pixel.
    - If all goes well, it subtracts v desire and the graftal is drawn.
    - If the less than v is subtracted, graftal may draw with less detail.
    - If less than some threshold (0.5 in paper), graftal is drawn at all.
  - To reduce "popping" graftals may initially be drawn with low detail, and quickly ramp up to full detail over a few frames and vice-versa when being removed.

Approach

- Drawing Graftals
  - Example of Fur graftals:

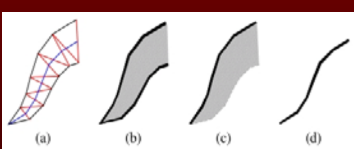
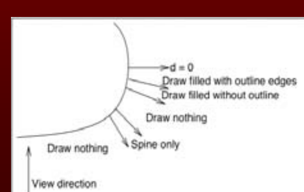


Figure 5 A fur graftal is based on a planar polyline and table of widths, used to construct a GL triangle strip (a). The graftal can render itself in three ways: It can draw a set of filled polygons with strokes along both borders (b) or just one (c); or it can draw just the spine (d).

Fur graftal geometry – Kowalski et al.

Approach

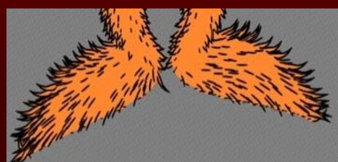
- Drawing Graftals
  - Graftals are drawn dependant on the eye vector and surface normal where graftal is attached.



Finding Graftal detail from surface normal and view direction – Kowalski, et al.

Approach

- Drawing Graftals
  - Graftals drawn in the plane of the surface normal and most nearly orthogonal to the eye vector
  - De Facto graftal placement: bending down.
  - Can be oriented to follow directions "painted" on texture patches, as on furry creature's feet:



Furry creature feet Kowalski, et al.

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  - Trees, Furry Creature, Dr. Seuss Scene
  - Videos
- Related Work
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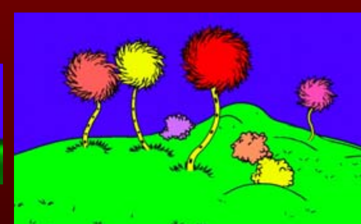
Results

Furry Creature – Kowalski, et al.

Tree – Kowalski, et al.

Results

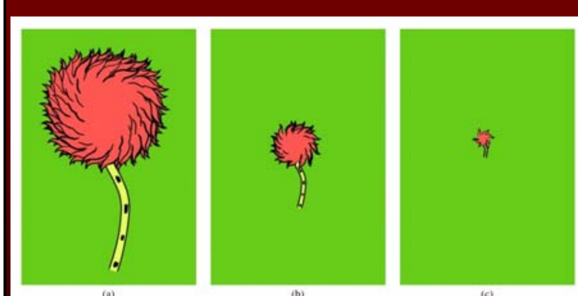


"Dr. Seuss" Rendered Scene – Kowalski, et al.

Related & Future Work

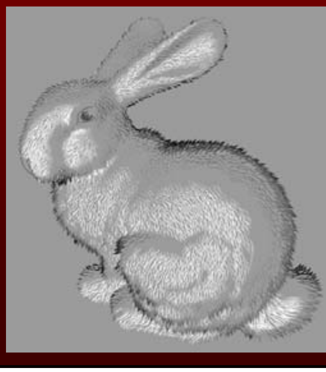
- Improve "popping"
  - DIA has no interframe consistency.
    - Could use alpha blending and fading but it's limited in it's usefulness.
  - Maintain graftals for back-facing surfaces so silhouette graftals do not pop in and out.
  - Maintain static graftals with level-hierarchy.
- Explore new styles
  - Example: bi-layered fur, one dark one light to suggest complex lighting effects.

Related & Future Work



Three-level detail hierarchy of Truffula tree – Kowalski, et al.

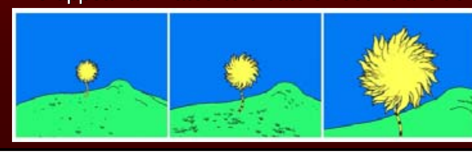
Related & Future Work



Dark and Light fur on Stanford Rabbit – Kowalski, et al.

Related & Future Work

- More recent paper “Art-based Rendering with Continuous Levels of Detail” (NPAR 2000)Addressed issues in original paper. (with Meier)
  - – Abstract procedural textures to a texture file.
  - – Static graftals, with complex level of detail model
  - – Look/behaviour of graftals as they disappear and re-appear animated to create smooth transitions.



Conclusion

- Good and interesting results for single-frame.
- Still some issues with animations, even in newer paper.
- Average computers today can handle large FPS without much problems.
- Limited to programmer-artists due to need for writing code to produce procedural textures.
- Lots of work to “describe” a scene with all it's different patches.
- Very similar to Stipple paper I presented before!

Conclusion

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The End

“Art Based Rendering of Fur, Grass, and Trees”
SIGGRAPH 99

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