Procedural rendering of grass field

XLIM - SIR

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Motivation

Create and render very complex virtual worlds

Highly detailed object

Generating 3D details of objects

- focus on small elements over surfaces.

Problems

Details mean sacrifices:

- Authoring time
- Memory cost / performance / visual quality trade off

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Motivation

Objectives

Provide a designing tool for artists

- easy creation / full control
- real-time / extremely low memory cost

Application examples

Large detailed landscapes

- Grass field
- Forest
- Flower field

Repetition of many small similar objects with variations.

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Vegetation scenes

Specific element of interest

Grass blade :

- Often in billions in vegetation scenes
- Simple shape

Blades shape

Variations of a similar basic shape

- Height
- Width
- Thickness
- Color

Basic parametric model easy to define.

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Grass field rendering

Rendering blades

3 types of representation

- surface representation
- image representation
- volume representation

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Grass field rendering

Surface representation

Single blades representation using geometry

- Precision
- Complexity

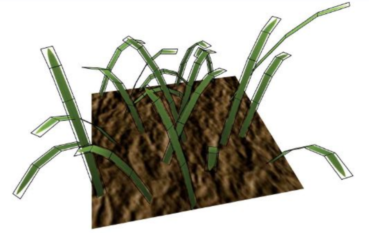

Figure : Grass blade textured geometry [Boulanger 2008]

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Grass field rendering

Image representation

Multiple blade representation using textured billboard, or simple texture on ground

- More adapted to real-time
- Repetition / control

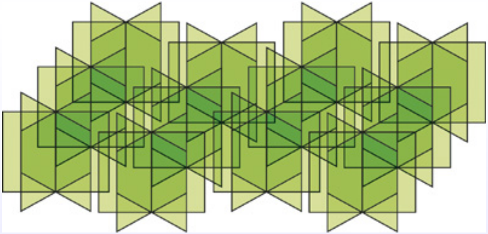

Figure : Cross textured billboard [Pelzer 2004]

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Volume representation

Multiple blade representation using sliced volumetric textures

- Precision/Performance
- Memory cost / control

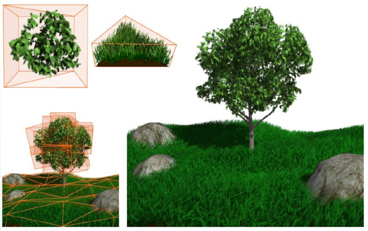

Figure : Volumetric billboard [Neyret and Decaudin 2009]

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Grass field rendering

In short

Several methods to render a grass field, choice = rendering objectives

- Manually created ?

Generating the field

Different approaches

- physics
- grammars
- statistics

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Grass field generation

Physical approach

Generating the field using physical simulation

- Particle system

Grammar generation

Generating the field using rules defined by the user

- L-System

Stochastic approach

Considering the field as a stochastic phenomenon

- Procedural texture generation

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Procedural texture generation

Reproduction of 2D stochastic phenomena

Based on statistics

Procedural noise functions to create stochastic patterns

- Per point evaluation
- Infinity pattern
- Constant time evaluation
- Low memory cost
- Parametric

Fulfils our objectives

Grass field as a noise

stochastic distribution of grass blades over a surface

Procedural texture generation

Sparse convolution noise

Distribution of kernel in evaluation space

$$N(x,y) \approx \sum_{i=0}^{N} w_i g(x - x_i, y - y_i)$$

Real-time computation

only 2D details

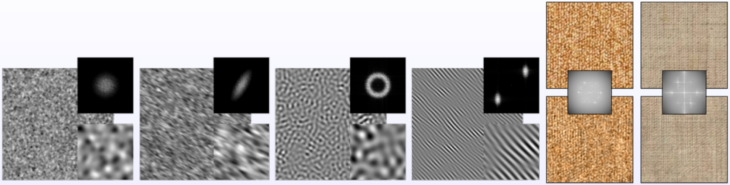

Figure : Convolution noise examples [Gilet et al. 2012] [Galerne et al. 2012]

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Volumetric noise modelisation

2D details to 3D details

Extend procedural texturing to 3D details generation

- Procedural Volumetric noise

Volumetric sparse convolution noise

Convolution of a 3D noise with a 3D gaussian type kernel

$$N(x,y,z) \approx \sum_{i=0}^{N} w_i k(x-x_i, y-y_i, z-z_i)$$

$$k(x,y,z) = Ke^{-\pi a f(x,y,z)}$$

Field modelisation

Grass field $\approx$ distribution of grass blade 3D kernels.

- Grass blade shape function

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Single blade kernel

Definition of a grass blade shape

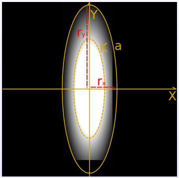
Basic shape formulation : extremely thin ellipsoid

Spatial shape control

Generic shape function of grass blades

$$f(x,y,z) = \sqrt{\frac{x^2}{r_x^2} + \frac{y^2}{r_y^2} + \frac{z^2}{r_z^2}}$$

(r_x, r_y, r_z) : size settings of the gaussian kernel's shape.



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Single blade kernel

Control of distribution

Blades randomly distributed with small variations

- specific distributions area : density maps
- Grass density : number of blades / surfel

Specific pattern

Blades distributed in tufts

- Number of tuft / surfel
- Number of blades / tuft

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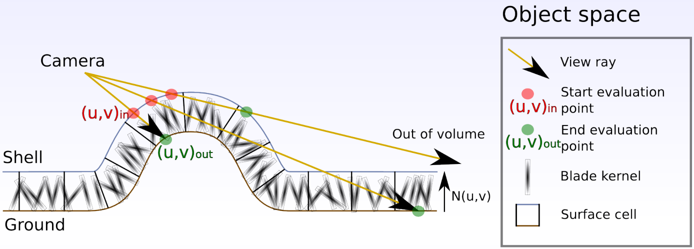
Single blade kernel



Rendering the single blades field

Based on splatting methods : Convolution of a supporting plane with the pixel

- Optimal slice : plane (X, Y) of the kernel

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Level of detail

Single blade definition

Accurate control but high complexity

- Need for coherent levels of detail for longer distance

Middle range approximation

Grass field defined as tufts of many grass blades

- One kernel to approximate the sum of N kernels
- Approximate the distribution and random variations mean

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Tuft kernel

Tuft shape function

Approximation of a grass tuft : $f_n(x, y, z)$

- Repeat n times the single blade pattern over θ and ϕ

$$f_N(p) = r_s(p)\sqrt{x(n,p)^2 + y(n,p)^2 + z(n,p)^2}$$

$$x(n,p) = \frac{(\cos(n\theta(p) + \omega_\theta)\sin(n\phi(p) + \omega_\phi))}{nr_x}$$

$$y(n,p) = \frac{(\sin(n\theta(p) + \omega_\theta)\sin(n\phi(p) + \omega_\phi))}{r_y}$$

$$z(n,p) = \frac{(\cos(n\phi(p) + \omega_\phi))}{nr_z}$$

Tuft kernel

Keeping the control

Use analytic parameters between single blades field and tuft field

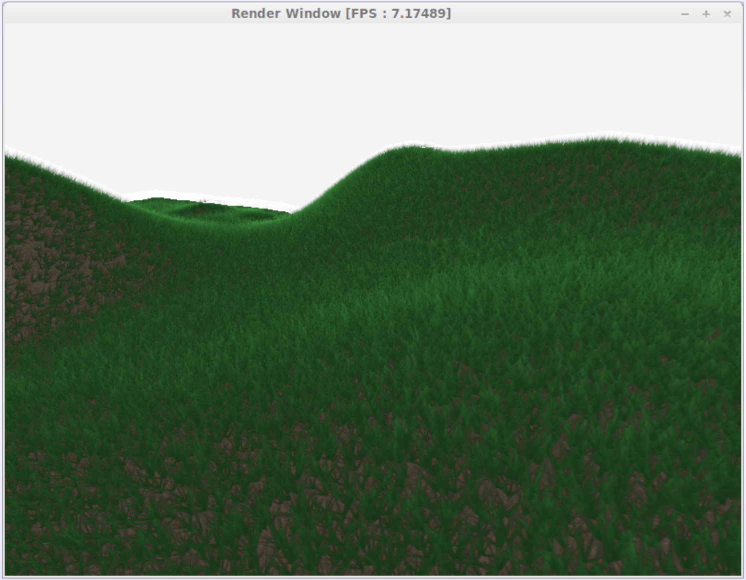
Rendering the tuft field

Same as single blades field rendering, but different supported plan chosen

- Slice the center of kernel, perpendicularly to the viewing ray.

Results for single blades

$\approx$ 800000 grass blades - Tested on GTX 690



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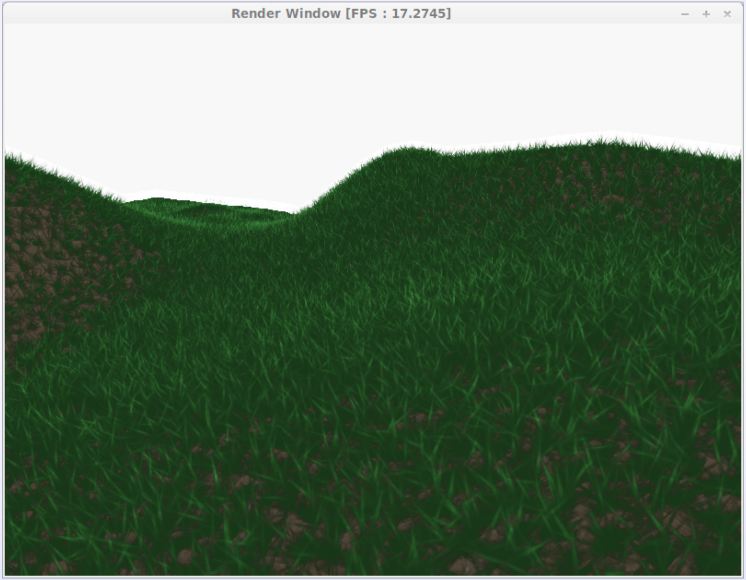
Tuft field

Work in progress



Conclusion

Modelisation tool

Procedural volumetric noise to create field of grass blades

- Real-time per pixel evaluation
- Extremely low memory cost

Interactive modelisation

From single blades to grass field

- Full control with parameters
- Analytic parameters between levels of detail

Future works

Spectral control

Analysing the power spectrum over several viewing angle

- Improve the tuft kernel formula
- improve anti aliasing
- Spectral coherency between levels of detail

Levels of detail

Improving both visual quality and reducing complexity with hierarchical levels of detail

- Visual coherency : geometry / noise / BRDF

Extension to various phenomena

Fur/hair, leaves ...

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Thank you !

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