Lightning

SDK demo explained
Previous Work

- Physical simulation using Dielectric Breakdown Model
  - Slow
  - Convolution with wide filter
- Structure from statistics
  - Raytracing / volume traversal
- Pregenerated animation
  - Not flexible
- CPU based generation

*http://gamma.cs.unc.edu/LIGHTNING/*
Algorithm

- Generate lightning structure
  - Random fractal L – system in the GS
  - Multiple iterations of subdivisions to generate more segments
- Animation

Rendering
- Constrained billboards

Post processing
- Blurring for glow & atmospheric scattering
Generation of Lightning Structure (1)

Initial seed segment

Jitter

Mix and match

Fork
Generation of Lightning Structure (2)

- Store line segment as single vertex and render points
  - contains also “up” vector for orientation of deviation
- GS emits 2 or 3 vertices, depending whether to jitter or fork
  - controlled by current (global) subdivision level
- Loop with StreamOut & BufferPingPong
- 5 to 6 subdivisions give good results
  - Between 64 and 729 segments per seed segment
  - $2 \times \text{fork} + 3 \times \text{jitter}$ looks good
Generation of Lightning Structure (3)

- Pseudo random numbers
  - DX9 style: store as textures
  - DX10 style: use integer / bit operations

- Code from Numerical Recipes
  (http://www.library.cornell.edu/nr/cbookcpdf.html)

- Ideally would have persistent seed value
- Instead use primitive ID as seed value
  - Variation across primitives
  - Animation is easy, just add time to seed value
    - Jumpy appearance, no change in topology

- Use base_value * e^{-decay * subdivision} for control
Generation of Lightning Structure (4)
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Rendering

- Rendering into separate off-screen RT, but using scene depth buffer, (with matching MSAA settings)
- Generate segment aligned and camera aligned quad with gradient between 2 colors
  - Vary width based on segment “level”
  - Gaps between segments
  - What about segments nearly orthogonal to view direction
Closing Gaps (2) — Starting point
Closing Gaps (2) — Starting point
Closing Gaps (1)

- Adjacent vertices unknown during subdivision
  - Cannot use them to adjust / connect quads 😞
- Tried image space growing and shrinking using dilation and erosion
  - Works for small resolutions / gaps
  - Leads to ugly artifacts 😞
Erosion / Dilation

Dilation

Erosion

Opening / Closing

Closing = dilation followed by erosion

Opening = erosion followed by dilation

Closing Gaps (3) — Dilation
Closing Gaps (3) — Dilation
Closing Gaps (4) — Dilation + Erosion
Closing Gaps (4) — Dilation + Erosion
Closing Gaps (5) - Solution

- Terminate each quad with a small square with a semicircular gradient
- Quads of neighbors overlap
  - Leads to overbright spots with additive blending
- Max blending deals with that:
  - `fragment_color = max(source, destination)`
  - If glow is used as a postprocessing step, additive blending works fine, i.e. it looks better
Closing Gaps (6) — Terminating Quads
Closing Gaps (6) — Terminating Quads
Closing Gaps (7) — Max Blending
Closing Gaps (7) — Max Blending
Post processing (1)

- Down sample to ¼ of width and height
  - Blurring less dependent of screen resolution
  - Could have minimal size of downsampled buffer
  - Faster 😊

- Separable Gaussian blur, e.g. 9 pixels support
  - Falloff $\sigma$ separate for RGB to fake atmospheric scattering

- Scale blurred version up and add to unblurred
  - Small glow
Post Processing (2)
Post Processing (2)
Results
Use cases (1)

- Weather effects
- Electric discharges
  - Beams between electrodes
  - Broken panels, computers
  - Combination with sparkles
- 42 kV fences
- Nebula / clouds in space games
Use cases (2)

- Force lightning
  - Radial lightning burst, restrict deviation to one plane
- Chain lightning
  - Targets can be tracked by spell caster
- Lighting missiles
  - Use 3D cross as seeding lines
- Lightning elementals
  - Use GS to extract edges of low resolution mesh as seed lines
Extensions

- Apply HDR
  - Render bright single pixel lines and let HDR resolve deal with glow
- Wide glow
  - Render dim and very wide bolts following coarse structure (e.g. 2 subdivision levels)
- Add lighting to lightning
  - Use segment centers of coarse subdivision as point light sources