Realistic and Fast Cloud Rendering in Computer Games

Niniane Wang
Software Engineer
Microsoft Flight Simulator
(now at Google Inc)

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Intro Video

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Agenda

- Previous Work
- 3-D Modeling + Art Pipeline
- Performance
- Shading model
- Animation: Formation and Dissipation
- Q & A

(All slide backgrounds are actual screenshots.)

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Previous Research

- Harris, SkyWorks
  - Use GPU to improve performance
  - Impostor for each cloud
- Dobashi
  - Metaballs
  - Anisotropic scattering
- Ebert, Blinn, others

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Previous Games

- Flight Simulator 2002
  - Each cloud is a single billboard
- Combat Flight Simulator 3
  - Each cloud is a few unique billboards
- IL-2 Sturmovik
  - Each cloud is a large number of small particles

Our Enhancements Over Previous Systems

- Many distinct cloud types (e.g. altocumulus, cumulonimbus)
- Art pipeline allows fine-grained control over model and shading
- Real-time performance (15 – 60 fps)
  - Even for overcast scenes

Concept: Cluster of Sprites

Each cloud is composed of 5 – 50 textured sprites.

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Cloud Creation

Each cloud is created by artists in 3D Studio Max.

- Use boxes to build cloud shape.
- Custom-written Max script to randomly fill boxes with sprites.
- Immediate visual feedback
- Export final model to a file to load into game

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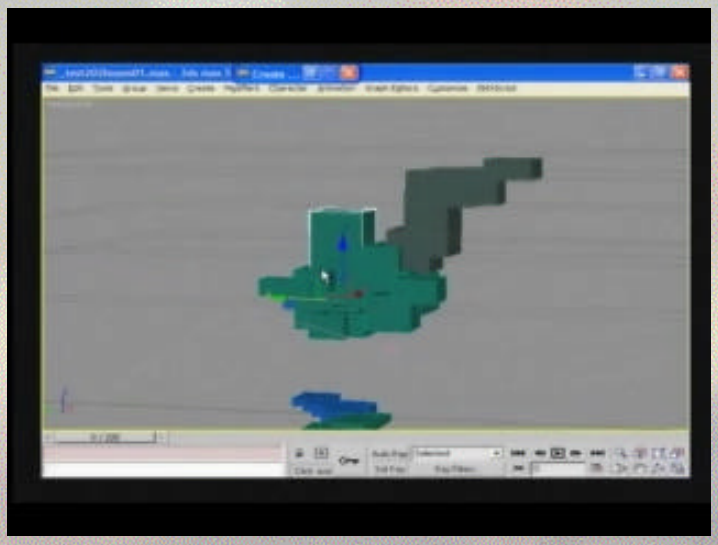
Cloud Creation Video



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Artist-specified Parameters

- # sprites to control cloud density
- Category (“stratus”, “solid cumulus”) to detemine texture
- Range for width and height of sprite
- Range of rotation for each sprite to give more variety

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Cloud Sprite Generation

- Artist presses a button…
- 3DS Max plug-in creates a list of randomly placed sprite centers
- It culls all sprites whose centers are within a "cull radius" of each other
  - Cull radius of 1/3 of cloud height is good for typical clouds, 1/5 for dense clouds

Real-World Cloud Types

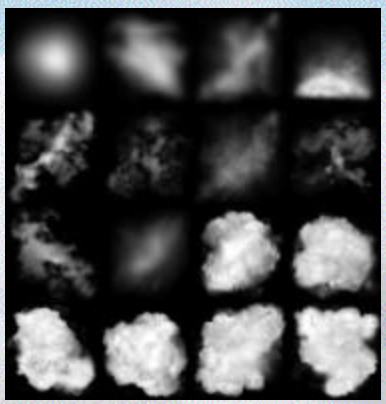
Real life cloud types have distinct looks

- Cumulus, stratus, cumulonimbus
- Sub-categories

Simulating Cloud Types

Mix and match 16 textures

- Solid puffs for cumulus, blurry puffs for stratus,
- Less video memory than using unique textures for each cloud



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Cloud Types Video

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In-Cloud Experience

- Sprite disappears as the camera passes through it
- Advantages of using cluster of sprites:
  - Consistent with cloud as seen from the outside – wispy parts are still wispy
  - Each cloud has different in-cloud experience, unlike with canned animation

In-cloud problems and solutions

- Initially, "parting of the Red Sea" problem
- Solve by locking the sprite within a distance
- This causes sprite edges to be visible
- Solution: Take dot product of lock angle and angle to camera, and adjust sprite transparency

In-Cloud Video

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Performance

- Requirements:
  - Flight Simulator must maintain 15 to 60 fps
  - Overcast scenes are the biggest challenge
  - Emulate real-world conditions ("Real-World Weather" feature)
  - Range of machines: 700 MHz to 3.0 GHz

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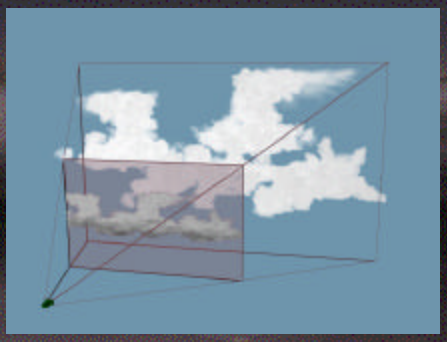
Performance: Impostors

Main bottleneck is in overdraw

Reduce overdraw by rendering multiple clouds into a single billboard



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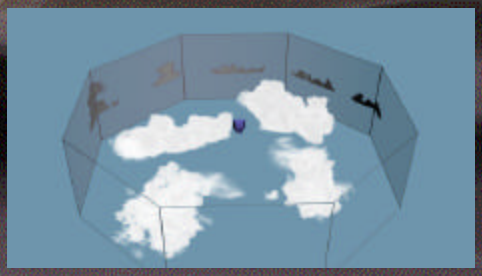
Ring of Impostors

Octagonal ring around user eyepoint

- Clouds within ring are drawn in 3-D



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Impostors

- Render same billboard across many frames
- Dynamically update impostor upon position/time change
  - Empirical results are 15% of impostor ring radius horizontally and 2% vertically
  - Time change of 10 minutes
- User can set ring radius
  - Smaller ring means better performance but more visual anomalies

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Impostors: Visual Anomalies

- Parallax
- Interaction with terrain and objects
- Rendering to texture not supported across all video card hardware
- Gray edges (the "silver lining")

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Fallback on older systems

- On old systems (< 450 MHz), even rendering a single block of 3-d sprites is too expensive
- Fall back to LoD scheme of single-billboard clouds
  - This is a degenerate case of our cluster of sprites model

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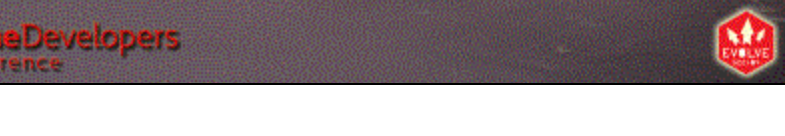
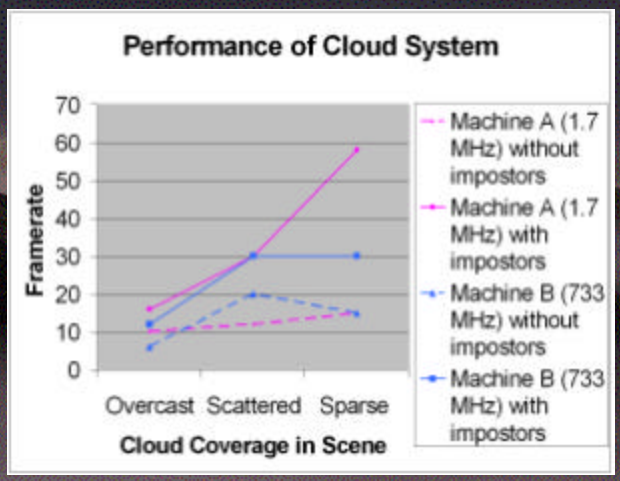


Performance Results



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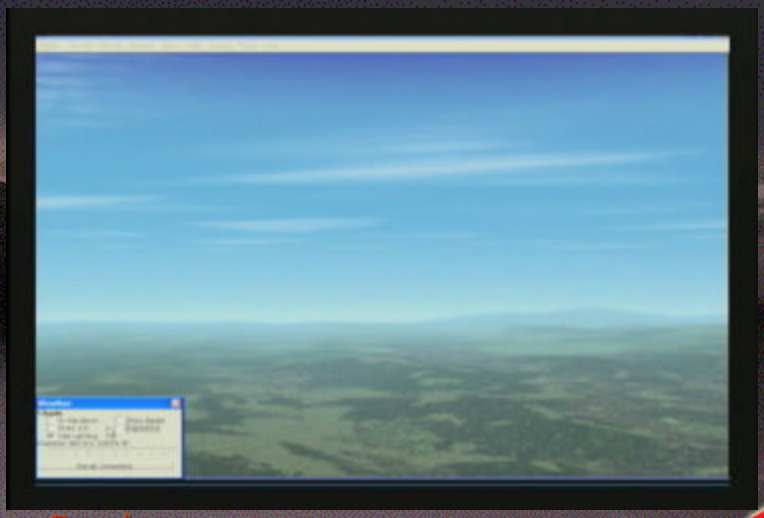
Impostor Video



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Shading

- We chose artist-driven system rather than simulating scattering of light
- Model lighting for different times of day
- Ambient and directional

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Ambient Shading

Simulate the filtering of light from the sky

- Clouds have dark bottoms, esp. cumulus
- Artist specifies 5 "color levels". Each level is a height with associated RGBA color.
  - Color also used to give cloud types their distinct look (e.g. more transparency for stratus)

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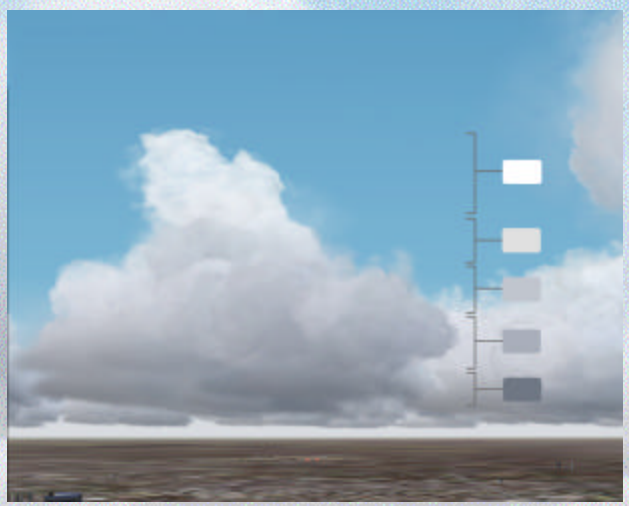
Illustration of Color Levels



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Ambient Shading Computation

- Interpolate maximum ambient RGBA for given time of day
- For each cloud vertex
  - Interpolate its ambient percentage of maximum value, based on vertex height within the cloud
  - Multiply by maximum RGBA

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Ambient Shading Video

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Directional Shading

- Parts of the cloud facing the sun receive more directional sunlight
- Artist specifies
  - Shading groups (sections of 1-30 sprites that are shaded as a unit)
  - Maximum directional color for a set of times throughout the day

Directional Shading Computation

- Find maximum directional RGBA for a given time of day
- For a vertex:
  - Compute dot product of (vector from cloud center to sun) with (vector from vertex to cloud center)
  - Multiply by interpolated maximum color

Illustration for Directional Light

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Directional Shading Video

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Animation

Adjust transparency values of sprites

- Form clouds from core first
  - Multiply cloud vertex with transparency factor based on its distance from cloud center
  - Render all of core first before edges
- Dissipate from edges

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Animation Video

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Limitations and Future Work

- Not suited for flat clouds (i.e. cirrus)
- Extension to fog and smoke
- Form animations on meteorological data and fluid simulation
- Pre-computed self-shadowing term

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Contact info, Q&A

- E-mail: niniane@ofb.net
- http://ofb.net/~niniane/clouds

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