3D Scientific Visualization

Oregon State University

Prof. Mike Bailey
Computer Science

mjb@cs.oregonstate.edu
http://eecs.oregonstate.edu/~mjb

Slides for this presentation are at:
http://eecs.oregonstate.edu/~mjb/geovis.pdf

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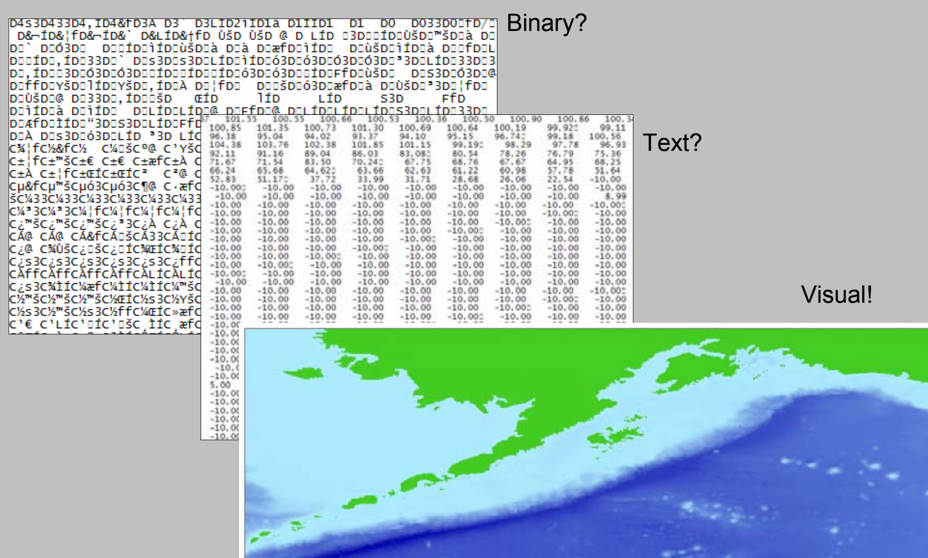
Why Visualize?



Visualization by Chris Janik

Goals for Visualization in the Geosciences

- Data Fusion – all data displayed together
- Interactive (i.e., fast)
- 3D
- Accessible to all: scientists, public, decision makers
- Reach into the future – don't do "visness as usual"
- Use the technology intelligently

Advanced Research (GPU) ⟷ Today's presentation ⟷ Useful Now (Vis Color Tips)

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Part I:

Using the GPU for Scientific Visualization

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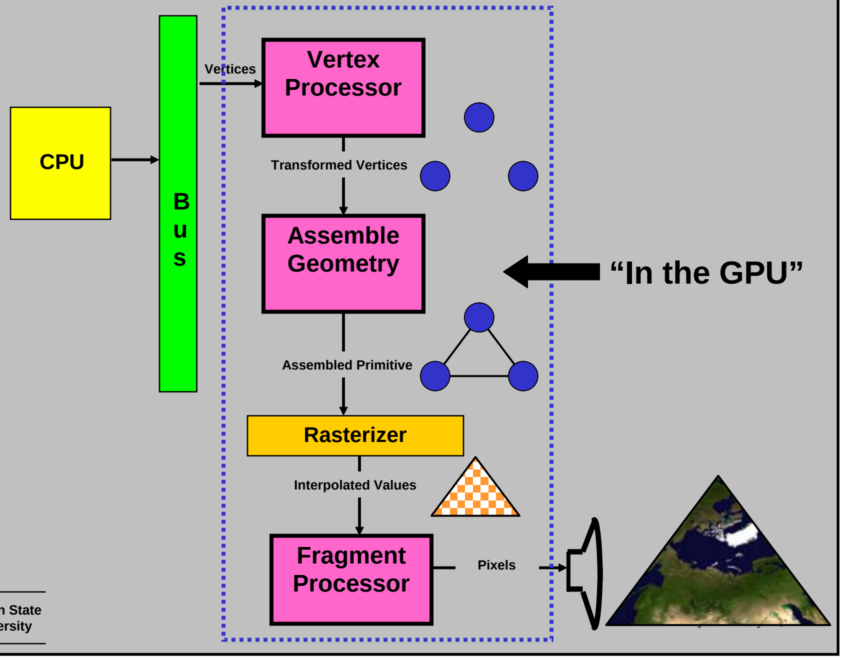
A Way-simplified View of Graphics Hardware



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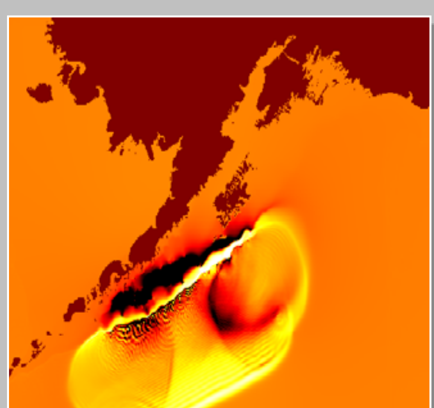
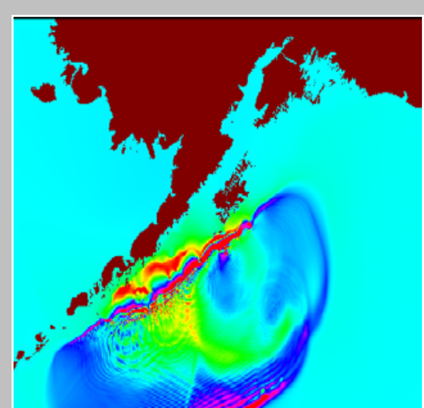
Don’t Send Colors to the GPU, Send the Raw Data





Use the GPU turn the data into graphics on-the-fly

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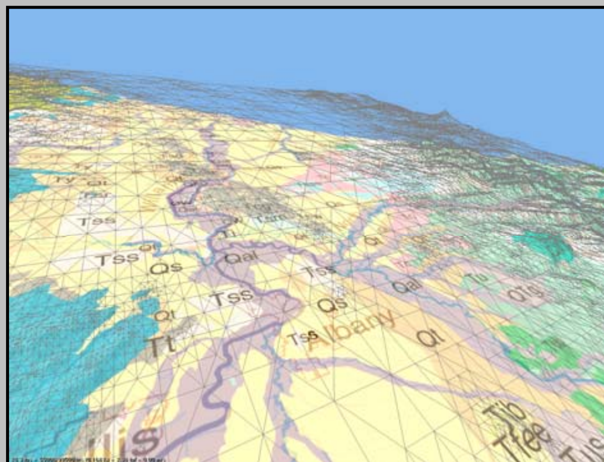
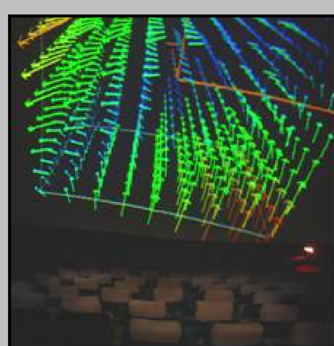
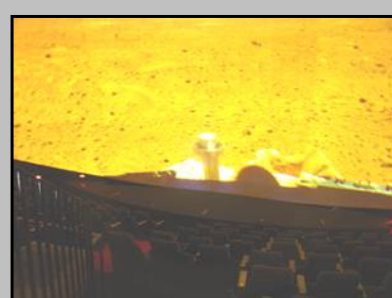
Terrain Explorer Program



Use the GPU to handle relations between datasets

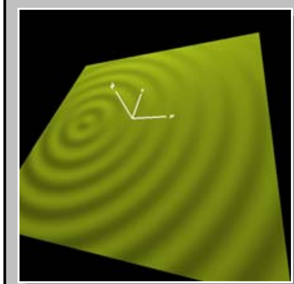
Dome Projection for Immersive Visualization



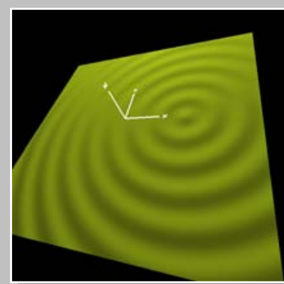


Use the GPU to perform nonlinear vertex transformations

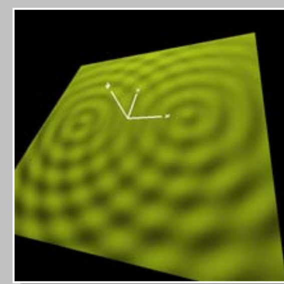
Bump-mapping to Create Apparent Surface Detail



Rock A Dropped



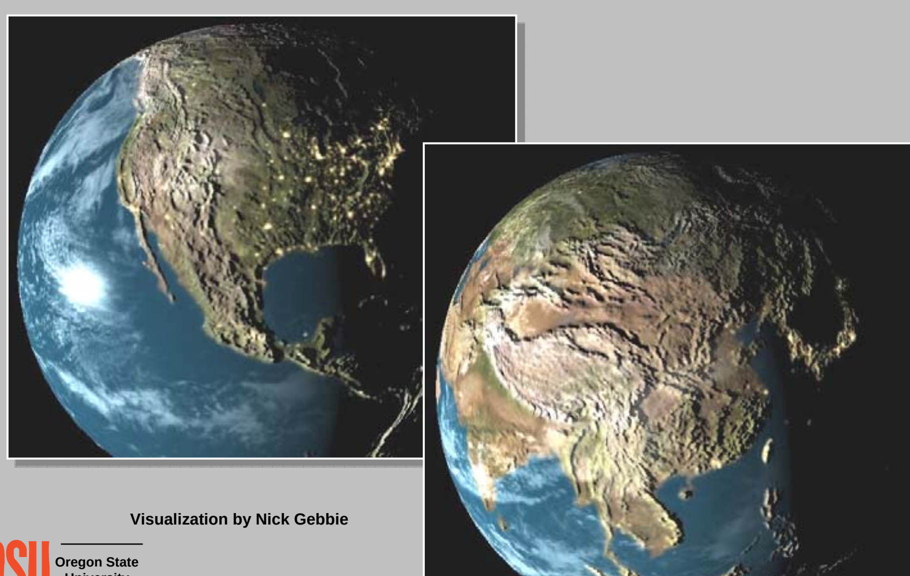
Rock B Dropped



Both Rocks Dropped

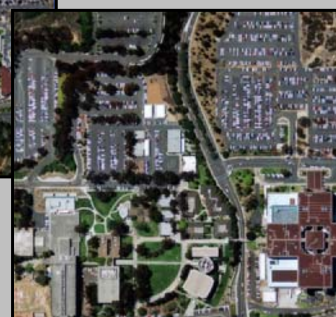
Use the GPU to create the *appearance* of height without geometrically creating height

Terrain Height Bump-Mapping



Visualization by Nick Gebbie

GPU-Based Dynamic Image Decompression plus Pan and Zoom



Use the GPU to work with aerial and satellite images that were originally larger than what will fit in graphics card memory

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GPU-Based Dynamic Image Decompression plus Pan and Zoom

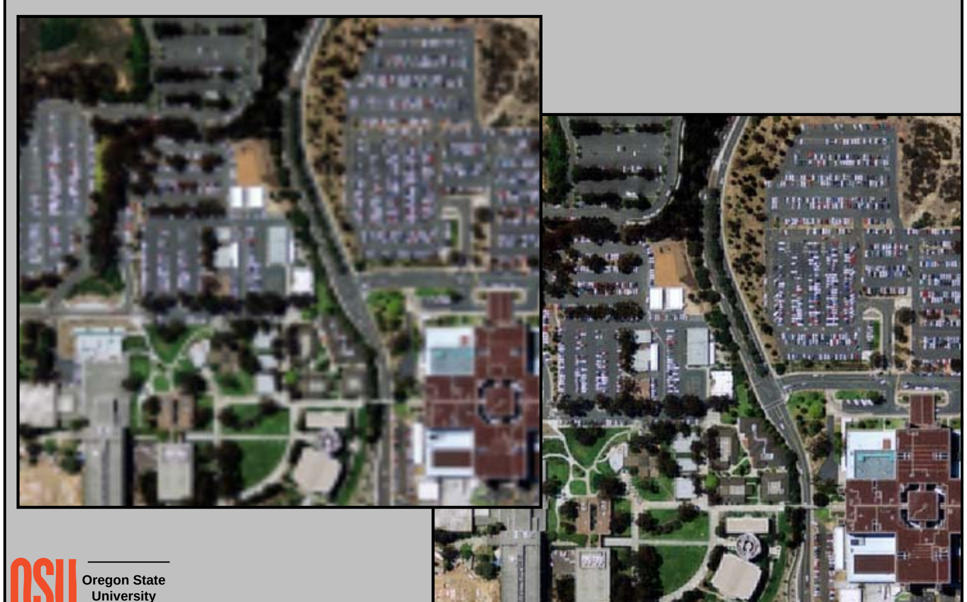

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Image Manipulation for Visualization: Un-Masking

$$I_{out} = (1.-t)*I_{dontwant} + t*I_{in}$$

Use the GPU to interactively manipulate images

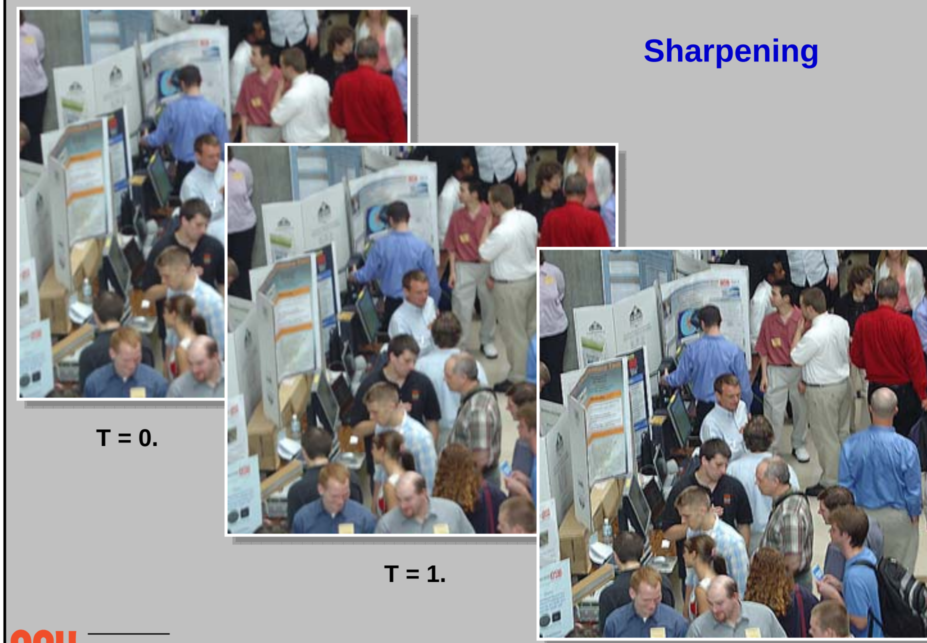
Sharpening

Blur Convolution:

$$B = \frac{1.}{16.}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

$$I_{dontwant} = I_{blur}$$

Sharpening



T = 0.

T = 1.

T = 2.

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Edge Detection

Horizontal and Vertical Sobel Convolutions:

$$H = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad V = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$S = \sqrt{H^2 + V^2} \qquad \Theta = \mathrm{atan2}(\ V, H\ )$$

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Edge Detection

T = 0.

T = 0.5

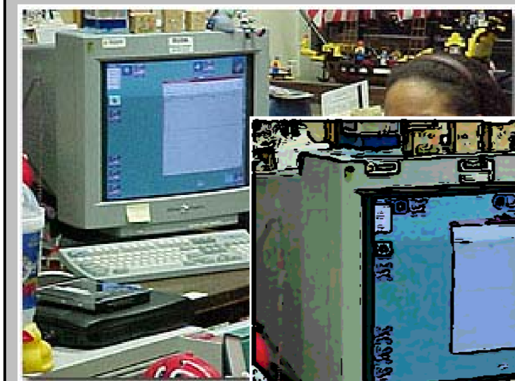
T = 1.

Non-photorealistic Rendering

Use the GPU to enhance scientific and engineering illustration

Non-photorealistic Rendering

Use the GPU to abuse your friends



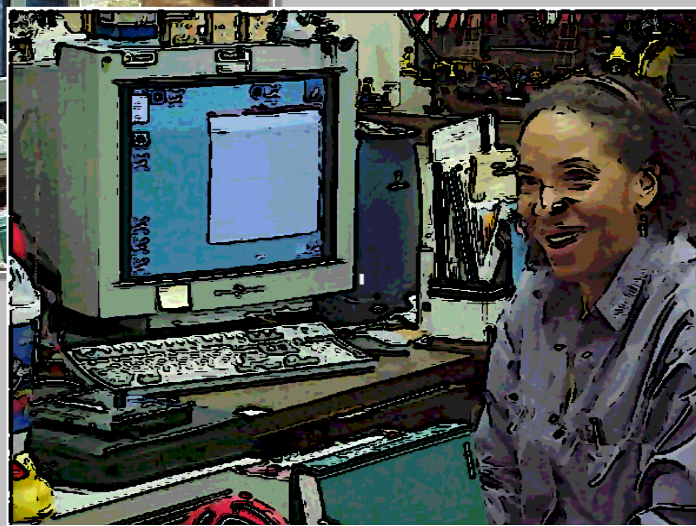


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Image Manipulation Example – Identify the Deserts

Use the GPU to examine image component characteristics to identify image regions

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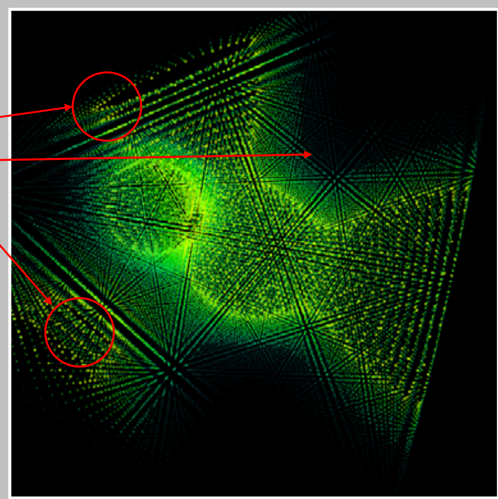
Visualization: Point Clouds

Can change:

- Color
- Alpha
- Pointsize



Use the GPU to interactively change the appearance of 3D data

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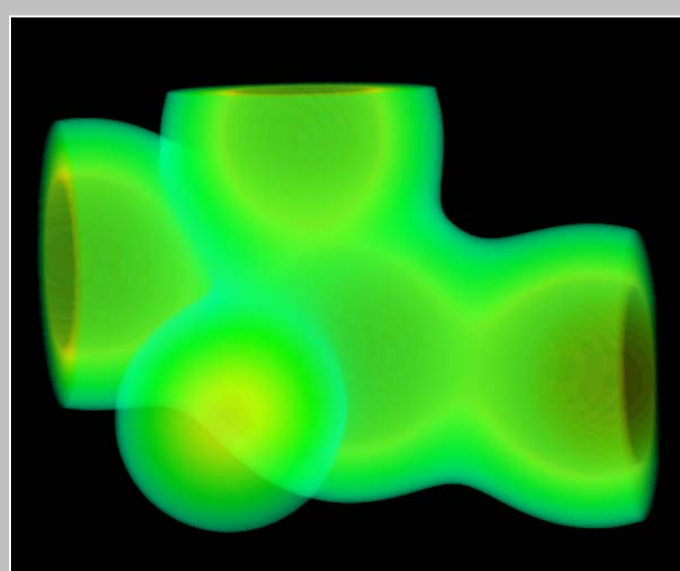
Visualization: Volume Rendering

Can change:

- Color
- Alpha



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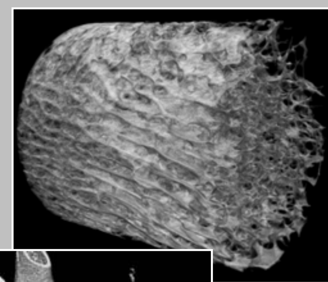
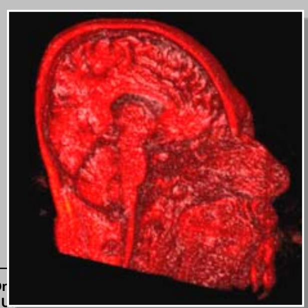
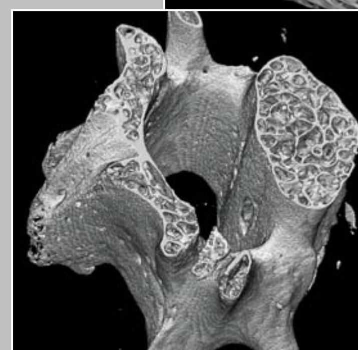
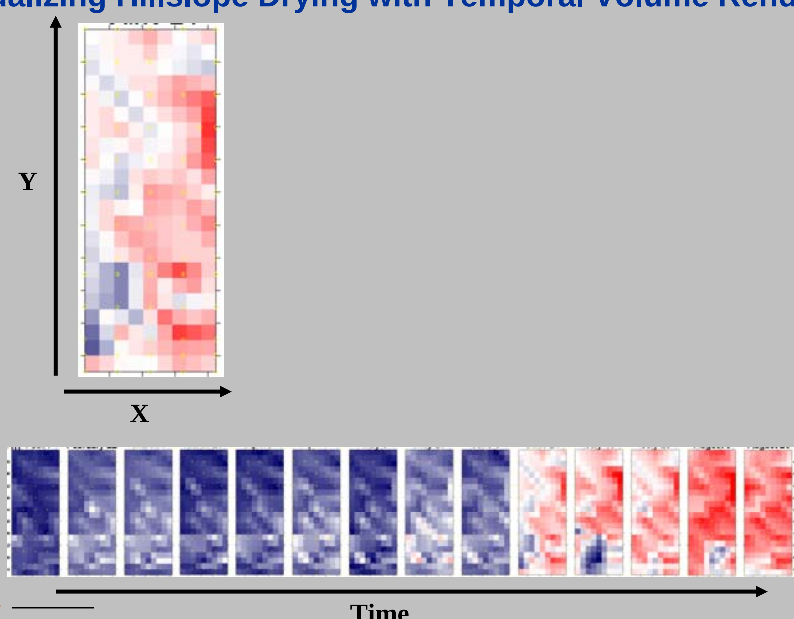
Volume Rendering in the Medical World







Visualizing Hillslope Drying with Temporal Volume Rendering



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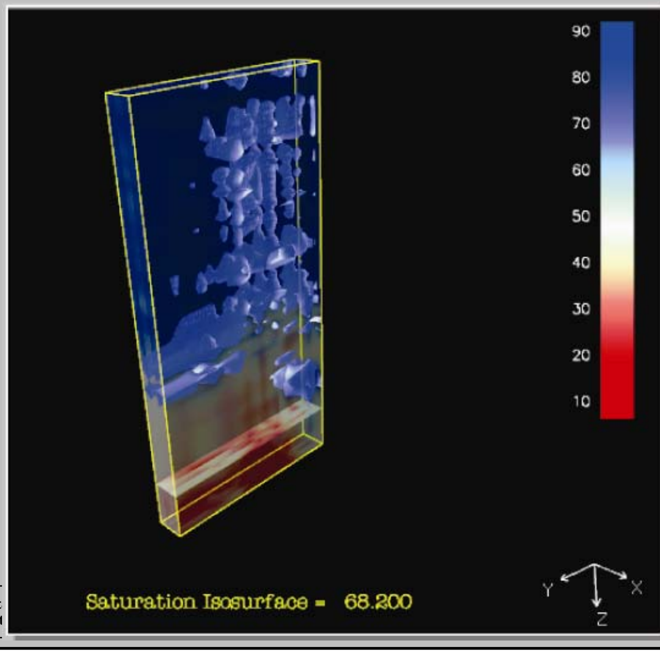
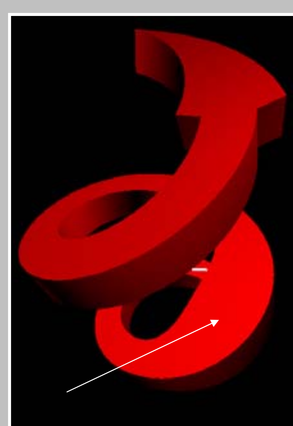
Visualizing Hillslope Drying with Temporal Volume Rendering

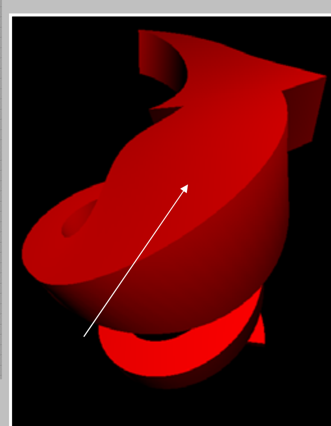


Visualization: Extruding Shapes Along Flow Lines

Use the GPU to show flow information

Add moving "humps" to create a peristaltic effect





Visualization: 2D Line Integral Convolution

At each fragment:

1. Find the flow field velocity vector there
2. Follow that vector in both directions
3. Blend in the colors at the other fragments along that vector

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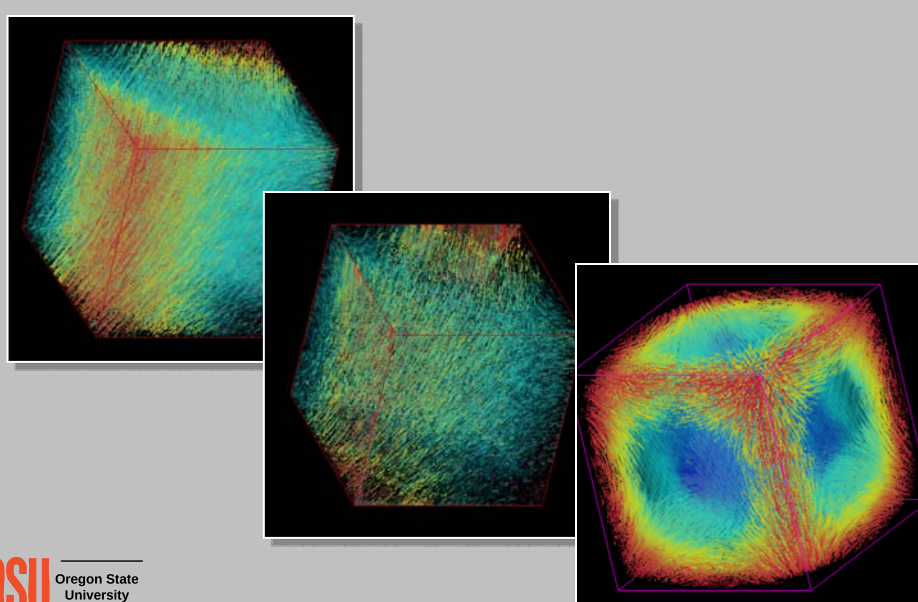
Visualization: 3D Line Integral Convolution



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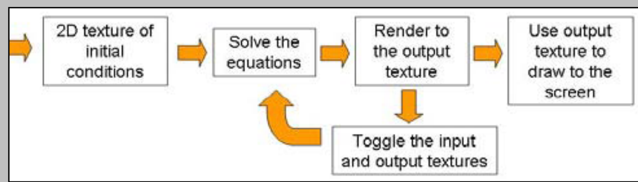
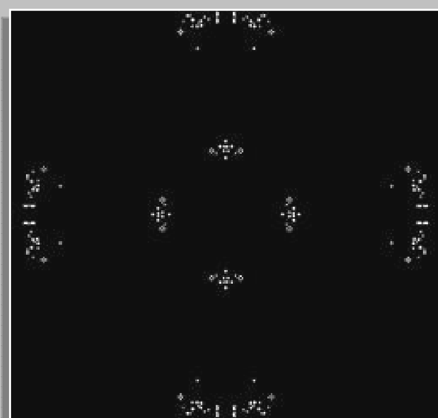
Finite Automata Computations in the GPU



Use the GPU as a general-purpose computer to compute the time steps of a simulation



We implemented John Conway's *Game of Life* – and achieved 300M computed pixels per second

Part II:

Some Good Rules of Thumb When Using Color for Scientific Visualization

What Makes a Good Contrast?

- Many people think simply adding color onto another color makes a good contrast
- In fact, a better measure is the Δ luminance
- Knowing this also helps if someone makes a grayscale photocopy of your color output

Color Alone Doesn’t Cut It !

I sure hope that my life does not depend on being able to read this quickly and accurately!

Luminance Contrast is Crucial !

I would prefer that my life depend on being able to read *this* quickly and accurately!

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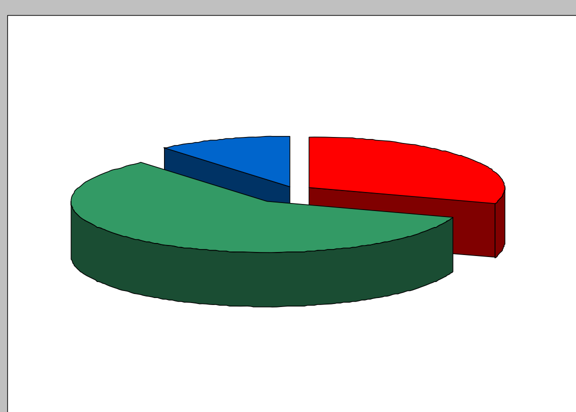
The Luminance Equation

Y = .30*Red + .59*Green + .11*Blue



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Luminance Table

	R	G	B	Y
Black	0.0	0.0	0.0	0.00
White	1.0	1.0	1.0	1.00
Red	1.0	0.0	0.0	0.30
Green	0.0	1.0	0.0	0.59
Blue	0.0	0.0	1.0	0.11
Cyan	0.0	1.0	1.0	0.70
Magenta	1.0	0.0	1.0	0.41
Orange	1.0	0.5	0.0	0.60
Yellow	1.0	1.0	0.0	0.89

≈ Contrast Table

	Black	White	Red	Green	Blue	Cyan	Magenta	Orange	Yellow
Black	0.00	1.00	0.30	0.59	0.11	0.70	0.41	0.60	0.89
White	1.00	0.00	0.70	0.41	0.89	0.30	0.59	0.41	0.11
Red	0.30	0.70	0.00	0.29	0.19	0.40	0.11	0.30	0.59
Green	0.59	0.41	0.29	0.00	0.48	0.11	0.18	0.01	0.30
Blue	0.11	0.89	0.19	0.48	0.00	0.59	0.30	0.49	0.78
Cyan	0.70	0.30	0.40	0.11	0.59	0.00	0.29	0.11	0.19
Magenta	0.41	0.59	0.11	0.18	0.30	0.29	0.00	0.19	0.48
Orange	0.60	0.41	0.30	0.01	0.49	0.11	0.19	0.00	0.30
Yellow	0.89	0.11	0.59	0.30	0.78	0.19	0.48	0.30	0.00

Look for a Δ luminance ≥ 0.40

	Black	Black	Black	Black	Black	Black	Black	Black
White		White	White	White	White	White	White	White
Red	Red		Red	Red	Red	Red	Red	Red
Yellow	Yellow	Yellow		Yellow	Yellow	Yellow	Yellow	Yellow
Green	Green	Green	Green	Green		Green	Green	Green
Blue	Blue	Blue	Blue	Blue	Blue	Blue		Blue

Do Not Attempt to Fight Pre-Established Color Meanings

Red:

Stop
On
Off
Dangerous
Hot
High stress
Oxygen
Shallow
Money loss

Green:

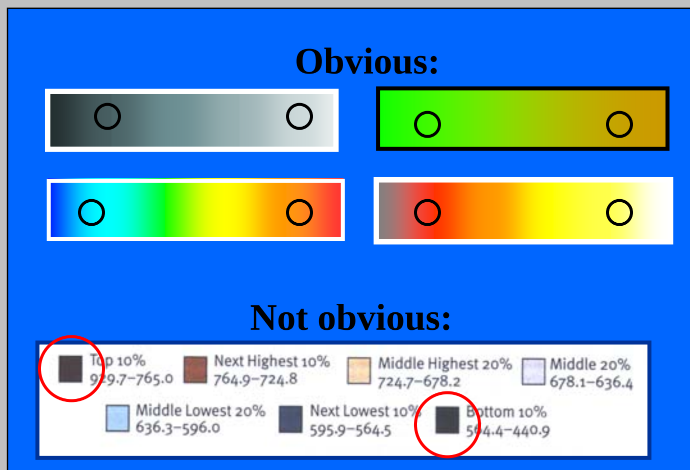
On
Plants
Carbon
Moving

Blue:

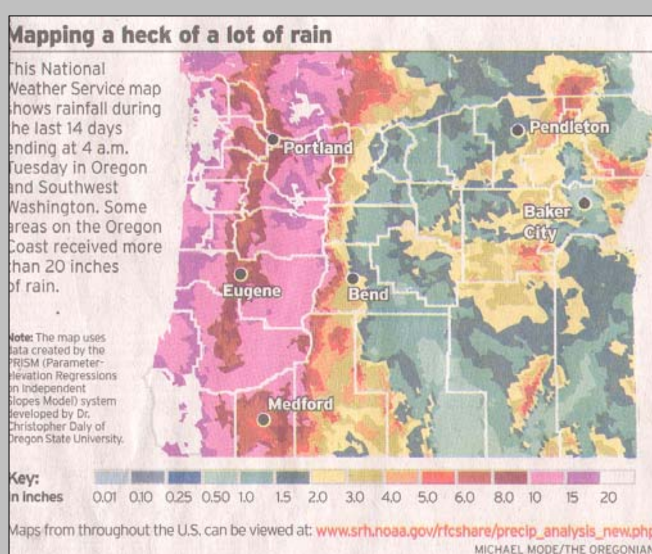
Cool
Safe
Deep
Nitrogen

Here's What's Important in a Color Scale:

Given any 2 colors, make it intuitively obvious which represents "higher" and which represents "lower"

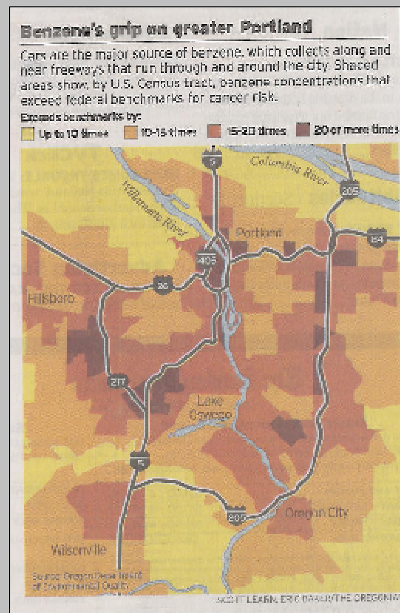


What was *The Oregonian* Thinking When They Chose This Color Scale?



Source:
The Oregonian,
January 11, 2006

Fortunately, They Got Better At It …



Source:
The Oregonian,
October 31, 2006

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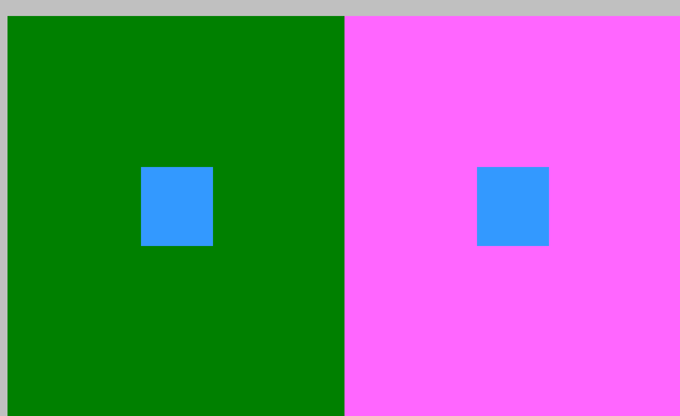
The Ability to Discriminate Colors Changes with the Surrounding Color



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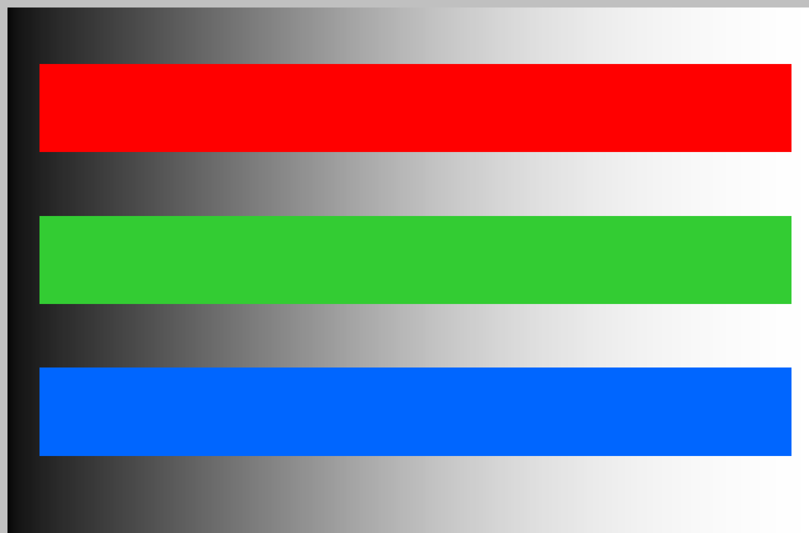

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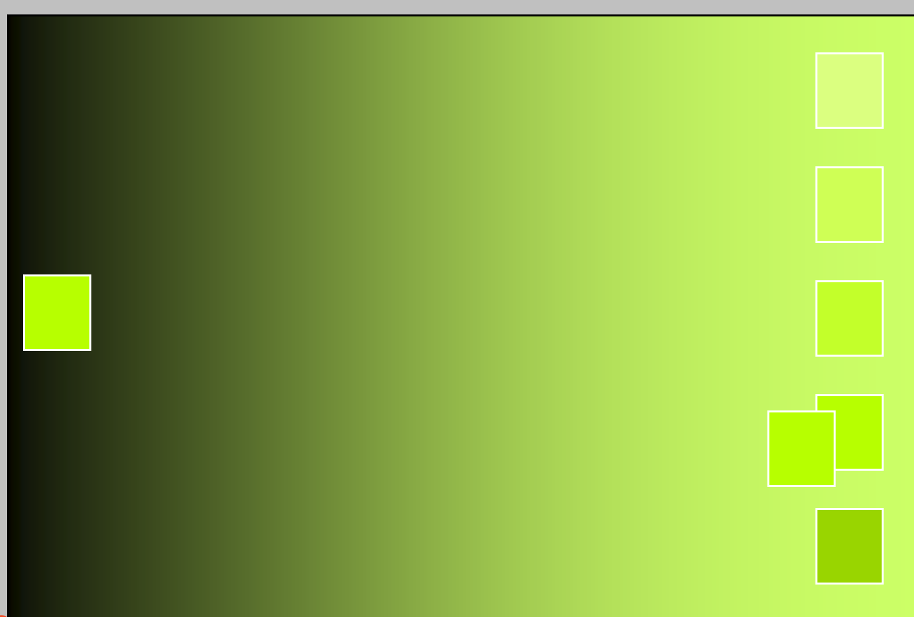

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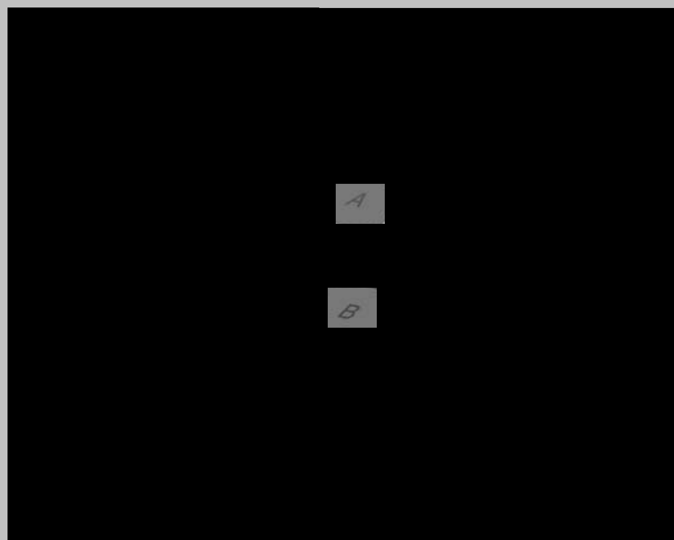
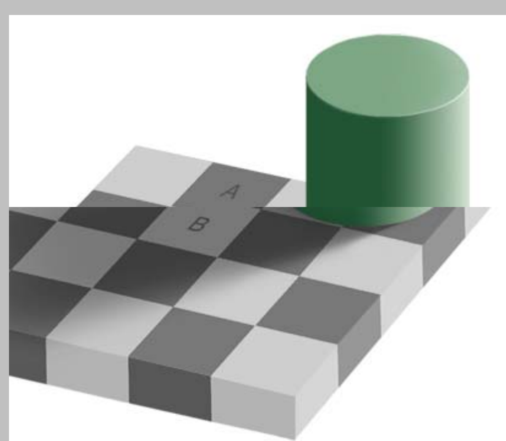
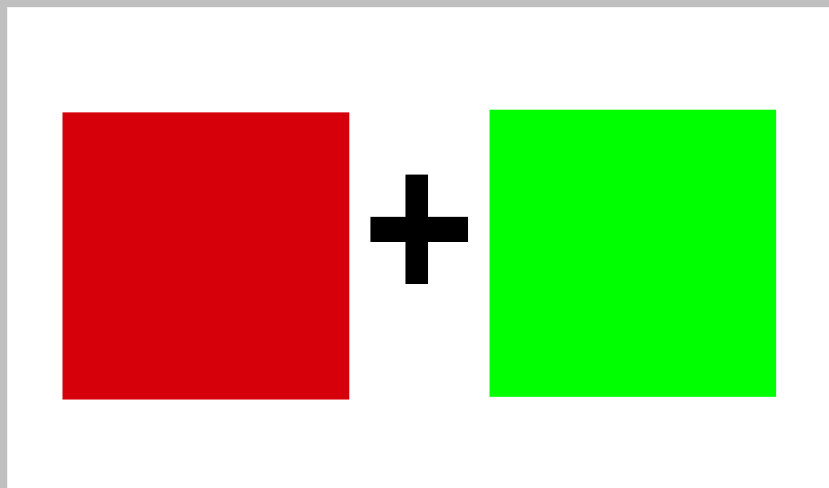

A
B


A
B

Afterimages



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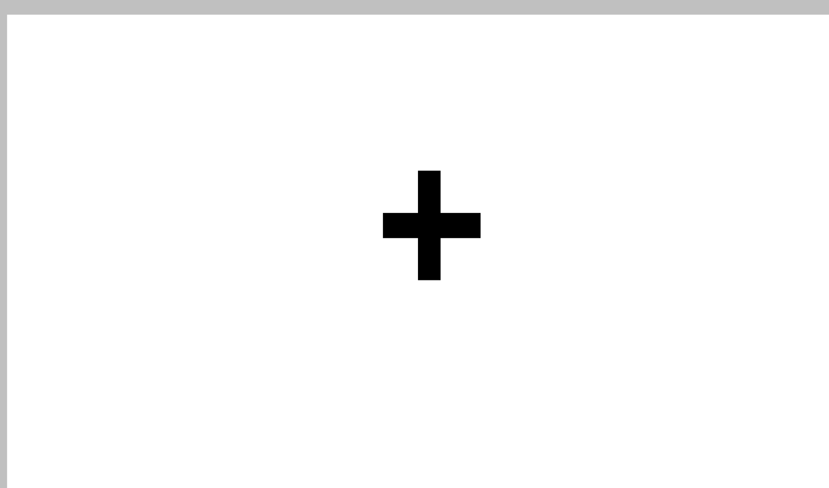
Afterimages



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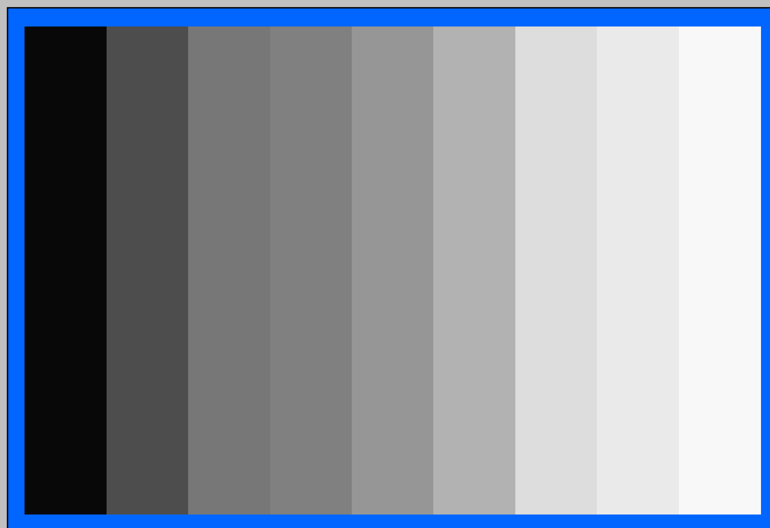
Beware of Mach Banding



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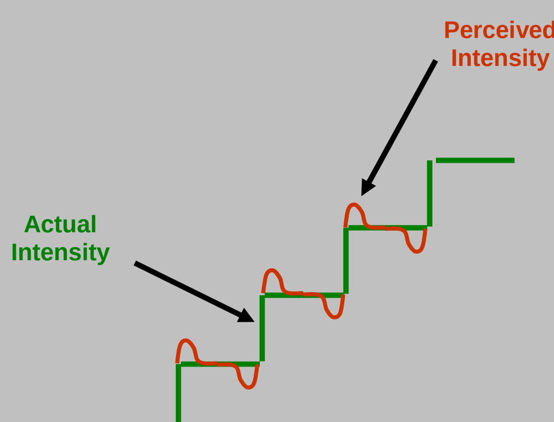
Beware of Mach Banding



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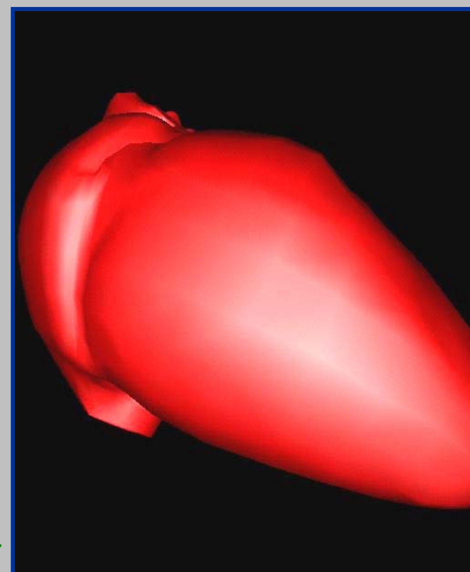
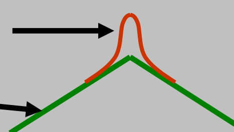
Beware of Mach Banding

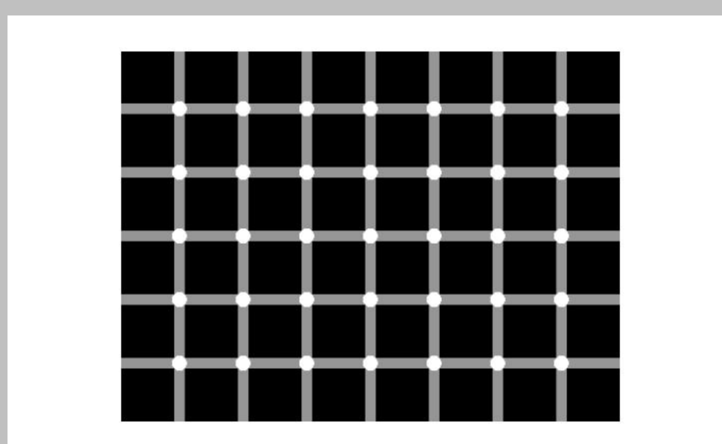


Perceived Intensity

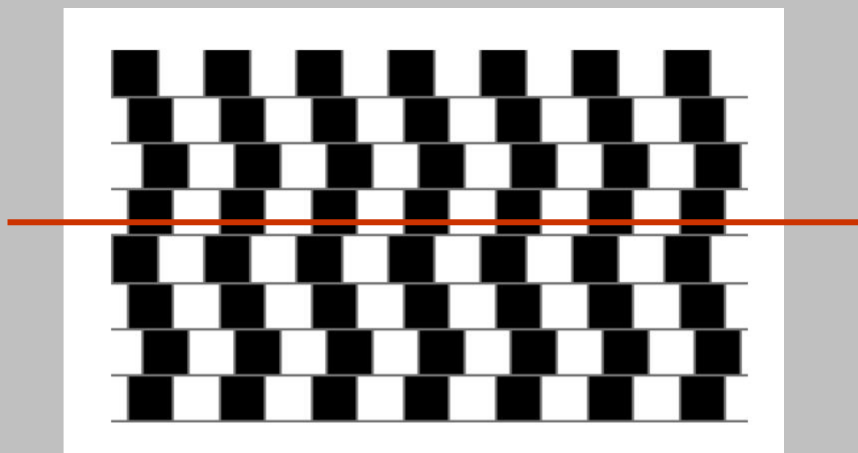
Actual Intensity

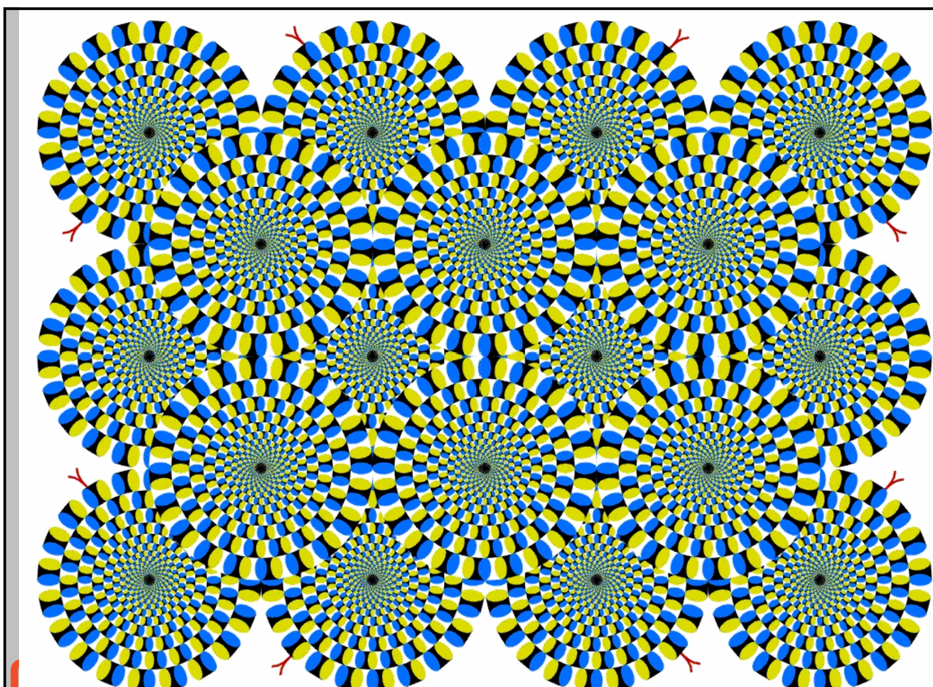


Beware of Lots of Other Stuff

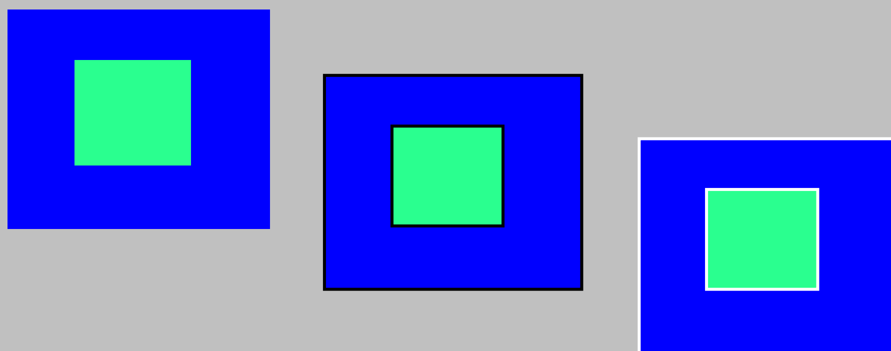


Beware of Lots of Other Stuff





Use a Black or White Line as the Boundary Between Colored Regions



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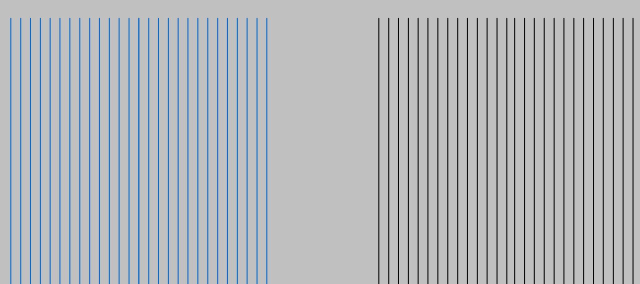
Watch the Use of Saturated Blues for Fast-Moving Items or Fine Detail



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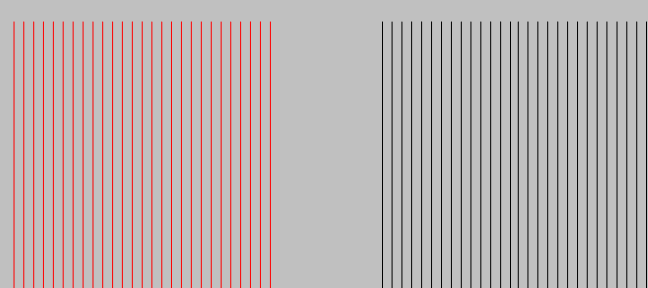
Watch the Use of Saturated Reds and Blues Together

Reds and Blues are on opposite ends of the color spectrum. It is hard for your eyes to focus on both.

Do Not Display High Spatial Frequencies in Color



Understand the Limitations of going from Workstations to NTSC

- Use less saturated colors due to color gamut considerations
- Expect an effective resolution of (at best) ~640x480
- Some colors have better video resolution than others

NTSC Cycles-of-Encoding per Scanline

What:	Cycles/Scanline:
Intensity	267
Orange-Blue	96
Purple-Green	35

Conclusions

- Be careful with the use of color. If done poorly, it detracts from the effective display of information. Above all, *do no harm*.
- GPU programming is one of the most exciting things that has ever happened to CG
- It enables application developers to have very tight control over graphics effects without sacrificing display performance
- It was really made for game development, but it has significant applications in visualization, imaging, and scientific computing
- OSU is one of the few universities that has an organized course in GPU Programming – CS 519 – next offered in Spring Quarter 2007. The pre-requisite is having taken any of the other CS graphics classes.

For more details on the class, see:
http://eecs.oregonstate.edu/~mjb/cs519

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Thank You !

Mike Bailey

mjb@cs.oregonstate.edu
http://eecs.oregonstate.edu/~mjb

Slides for this presentation are at:
http://eecs.oregonstate.edu/~mjb/geovis.pdf

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