NVISION 08
THE WORLD OF VISUAL COMPUTING

Beautiful Women of the Future

Kevin Bjorke, NVIDIA

Beautiful Women of the Future

Image: Darks Adria

Image: Lunarose Graves

Agenda

- **Background**
- **Characters**
  - **Their roles in gaming**
- **Techniques**
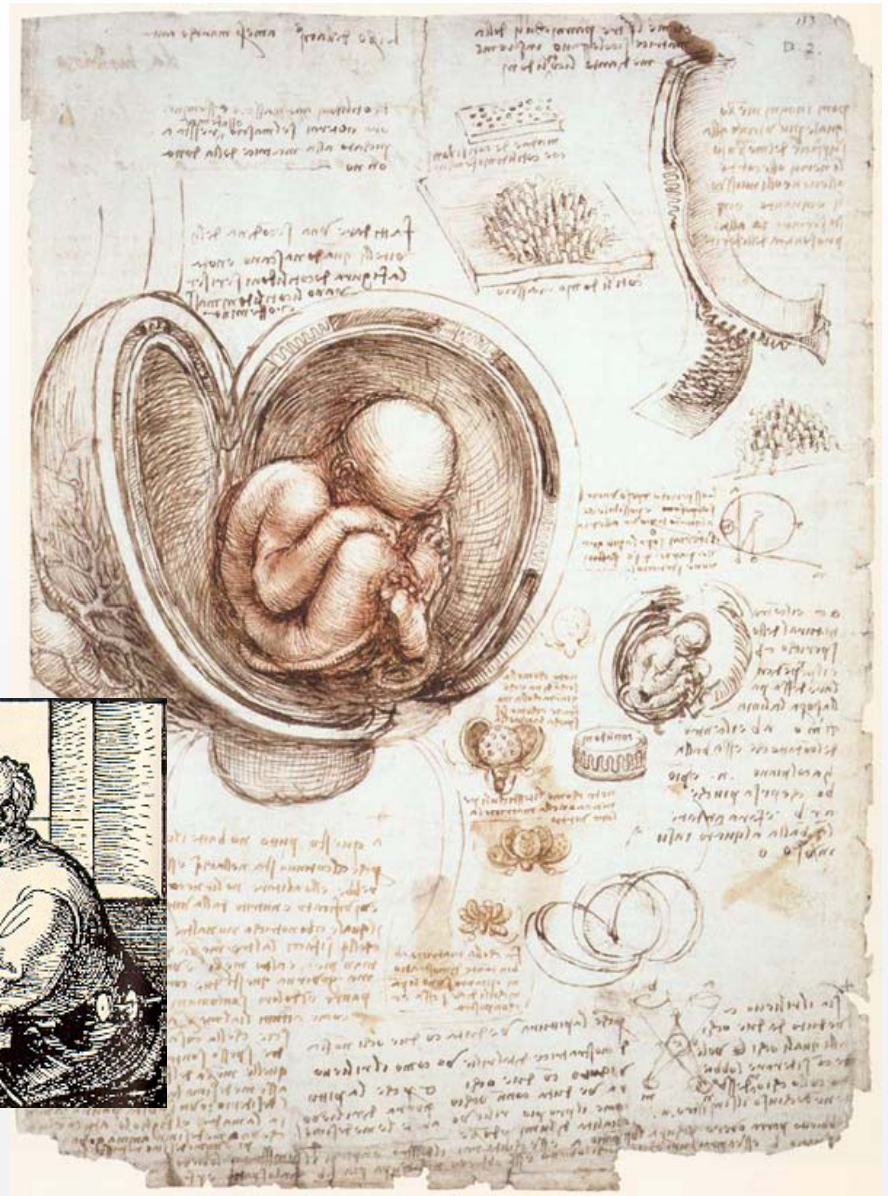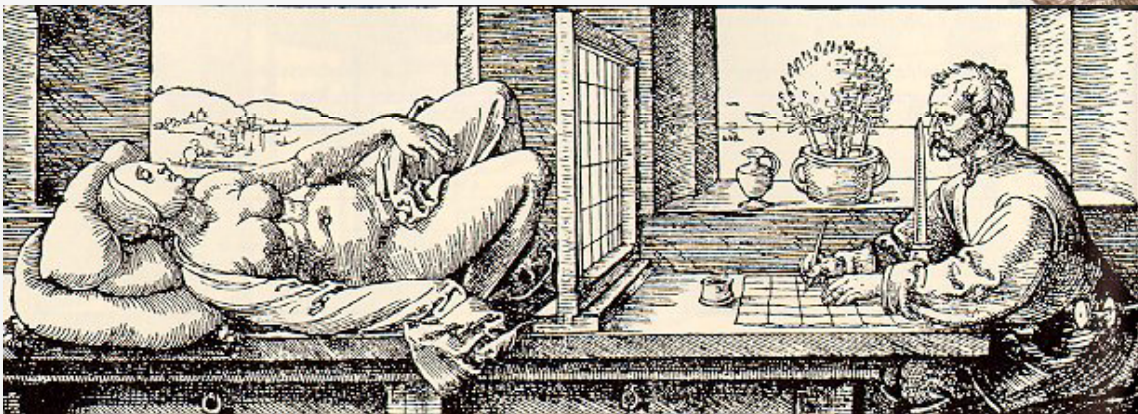 - **Behavior**
  - **Clothing**
  - **Skin**
  - **Eyes**
  - **Hair**

6'

Technical Artists

…have always
been around!

The Happiness Business

Moore's Law to the ^{N}

Fastest GPU

Relative
Floating Point
Performance

Fastest CPU

80
70
60
50
40
30
20
10
0

2002 2003 2004 2005 2006

Changing Formats

8x6   10x7   10x12   19x12   25x16   32x24
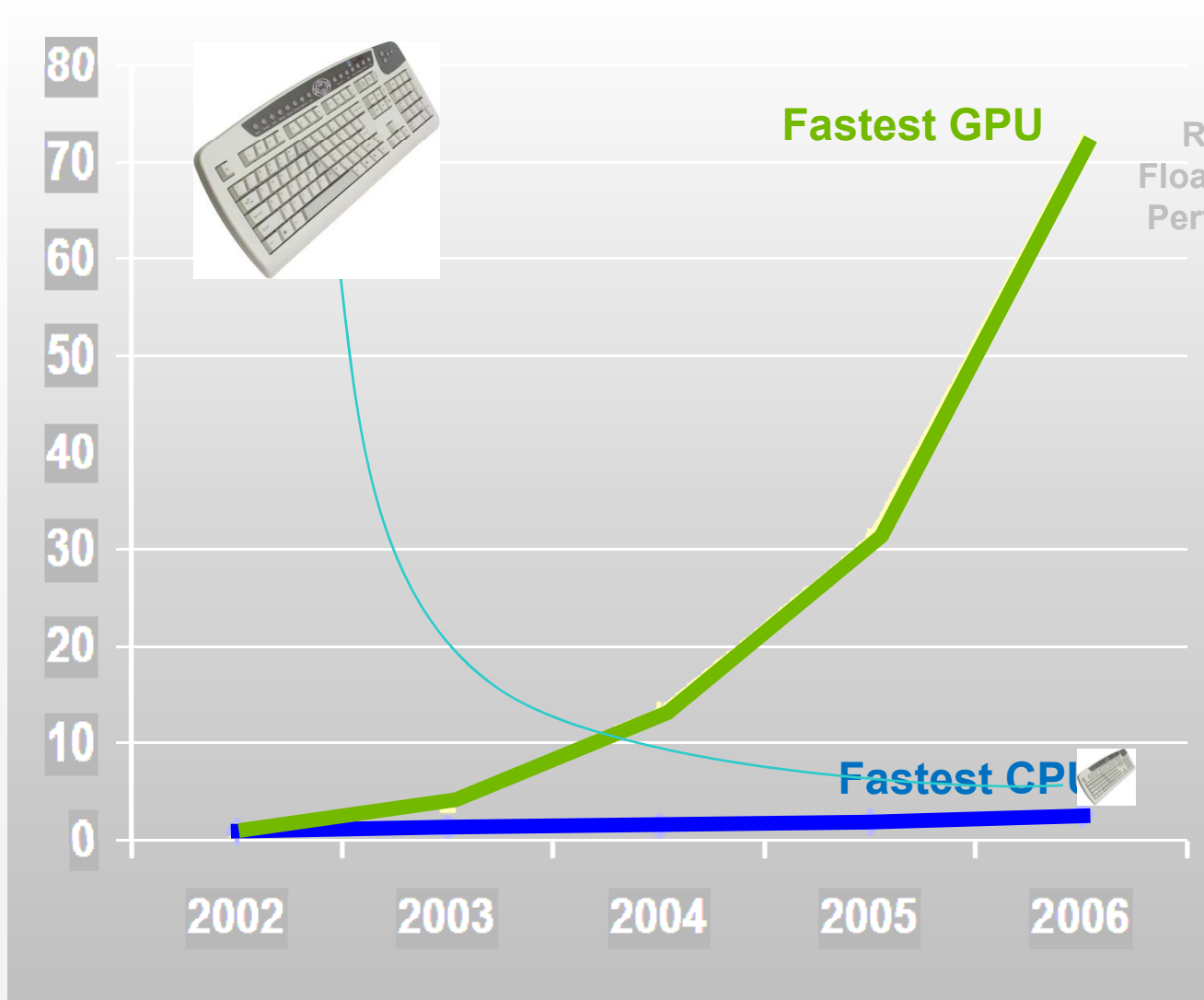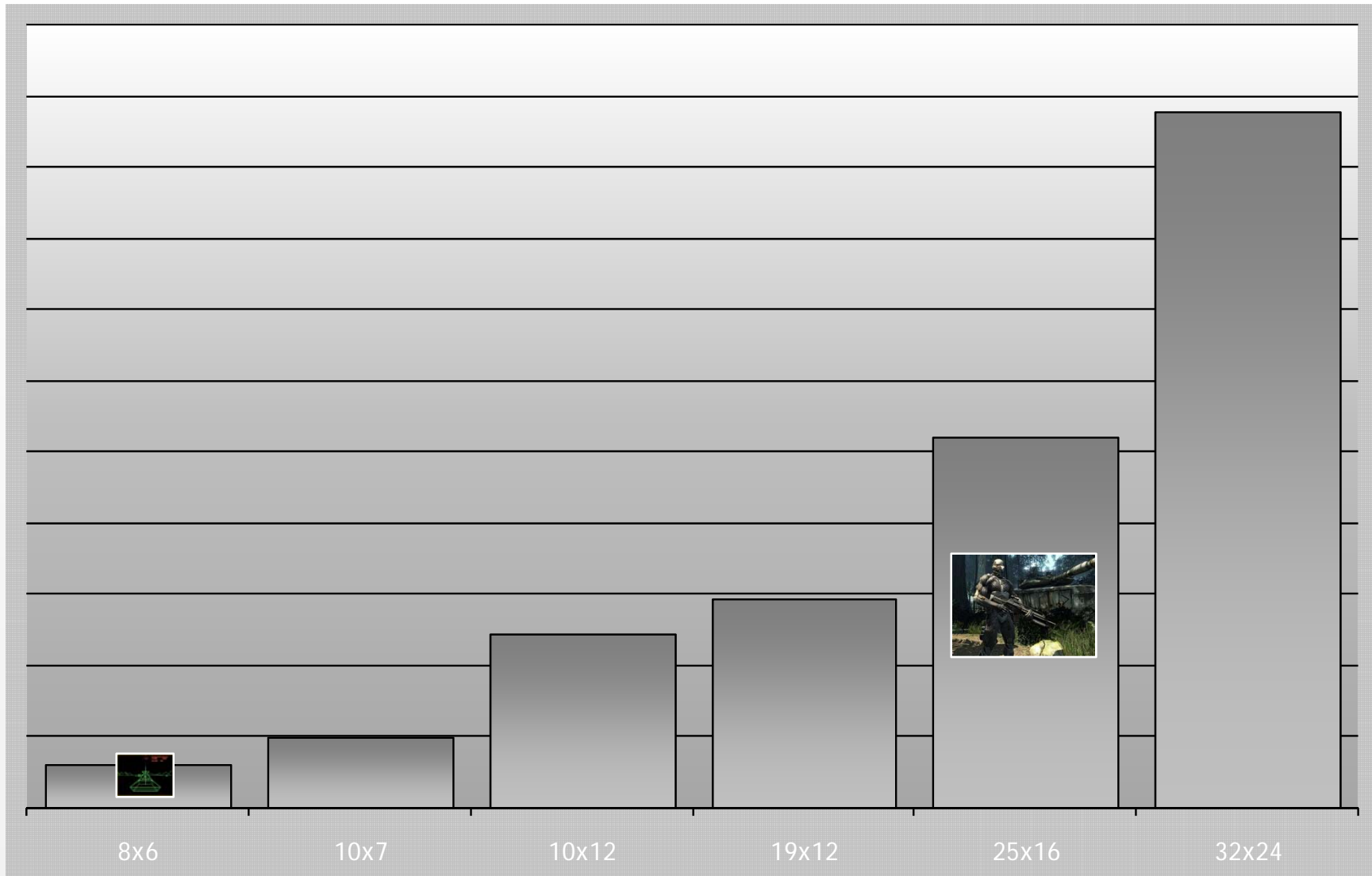
Stampeding Content

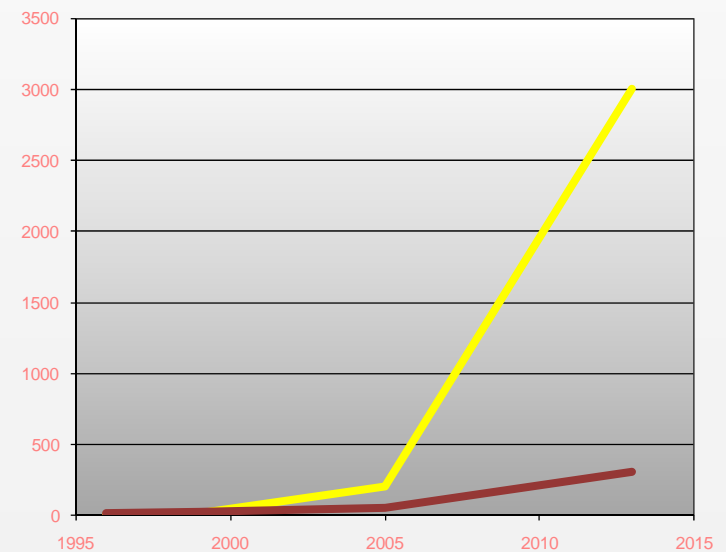- **From Evan Hirsch at Gamefest:**
  - **1996: 4MB Artwork, 8-12 人**
  - **1999: 10-15MB Artwork, 15-20 人**
  - **2005: 200+ MB Artwork, 25-??? 人**
- **Where would this trend lead?**
  - **2013: 3-5GB Artwork, 300+ 人?**
- **Can *anyone* afford this?**

Rising Triple-A Game Budgets

$12,000,000

$7,200,000

$4,000,000

$2,400,000

$150,000

1993-   1995-   1998-   2001-   2005-

Source: R Koster
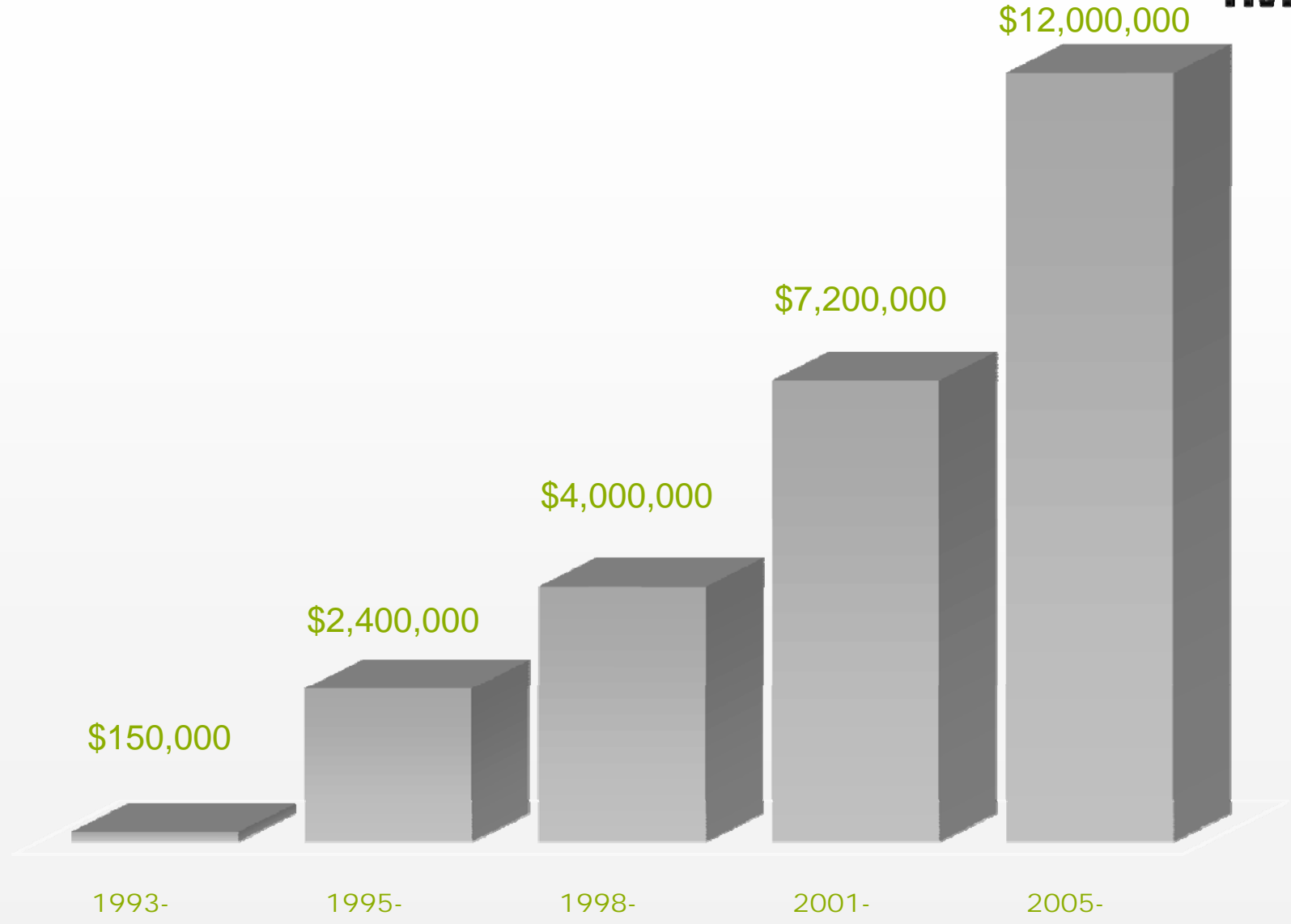
Reining-In Content Budgets

- **Technology: Friend and Foe**
- **Foe:**
  - Added sophistication raises the danger of ever-more-burdensome noodling
- **Friend:**
  - GPU physics and shading effects fill space and time according to resolution
  - In a sense, they can be "free artwork"
  - Clever shading and physics can extend the usefulness and life of lower-res assets

Daddy, Where Do Game Characters Come From?

- Traditional games rarely have "characters"
- Most big name video games *do*
- *How did this happen?*

Two Branches of Art

Two Branches of Art

The Irish Jig
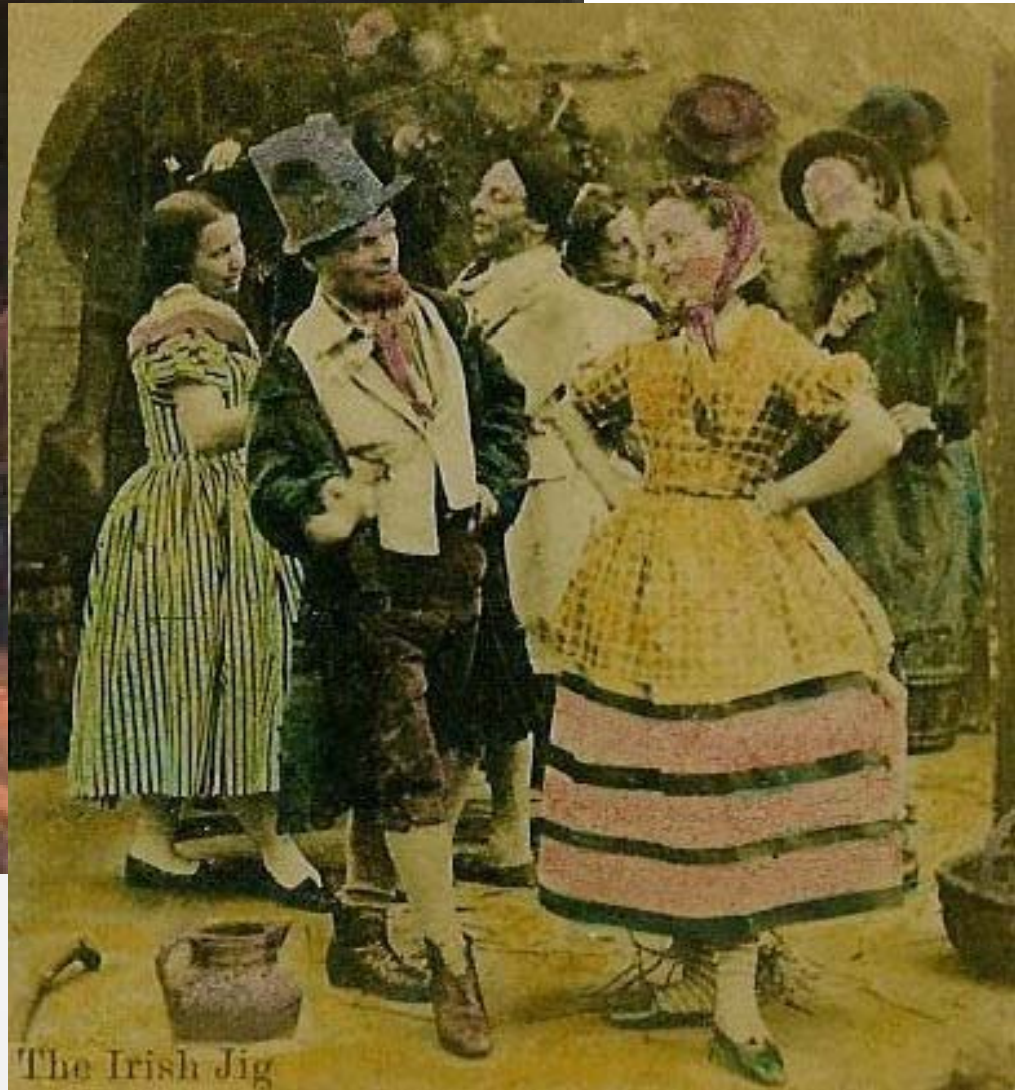
The Industrial Revolution
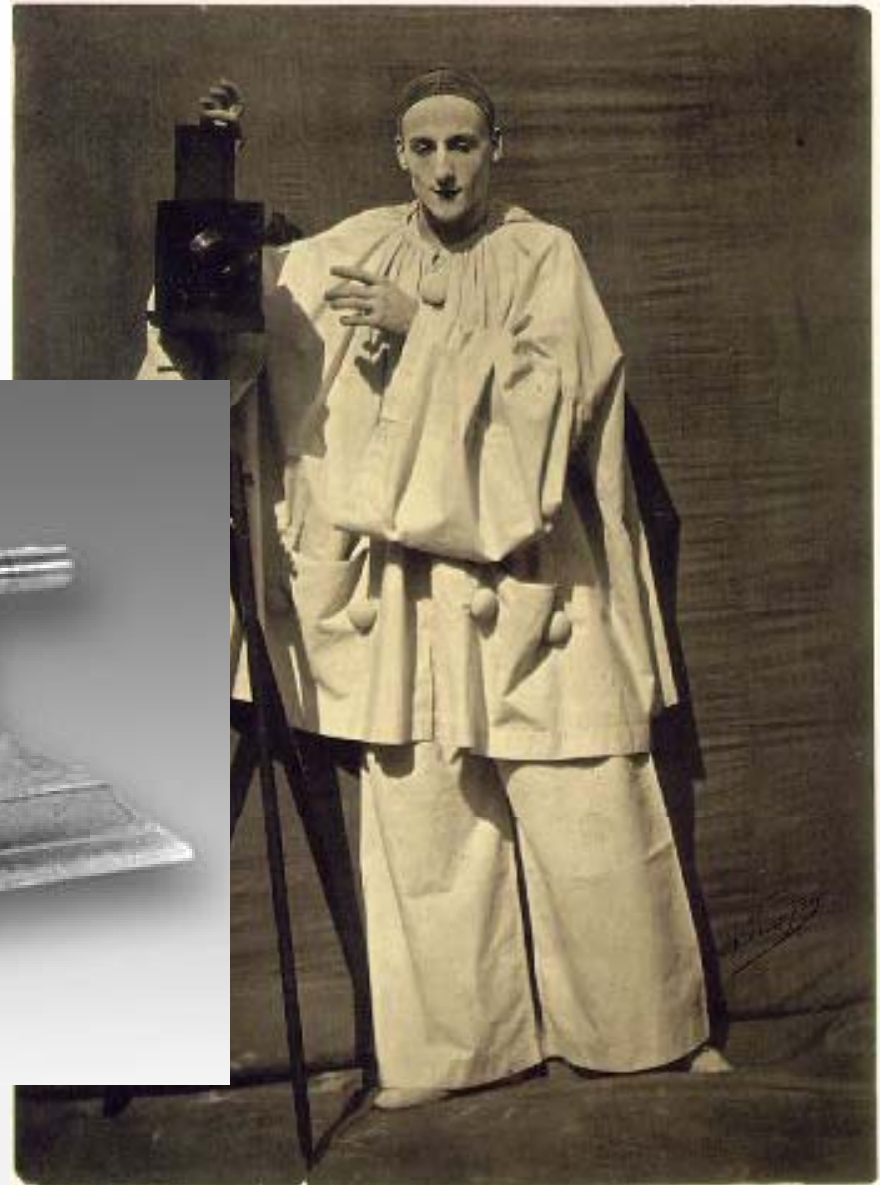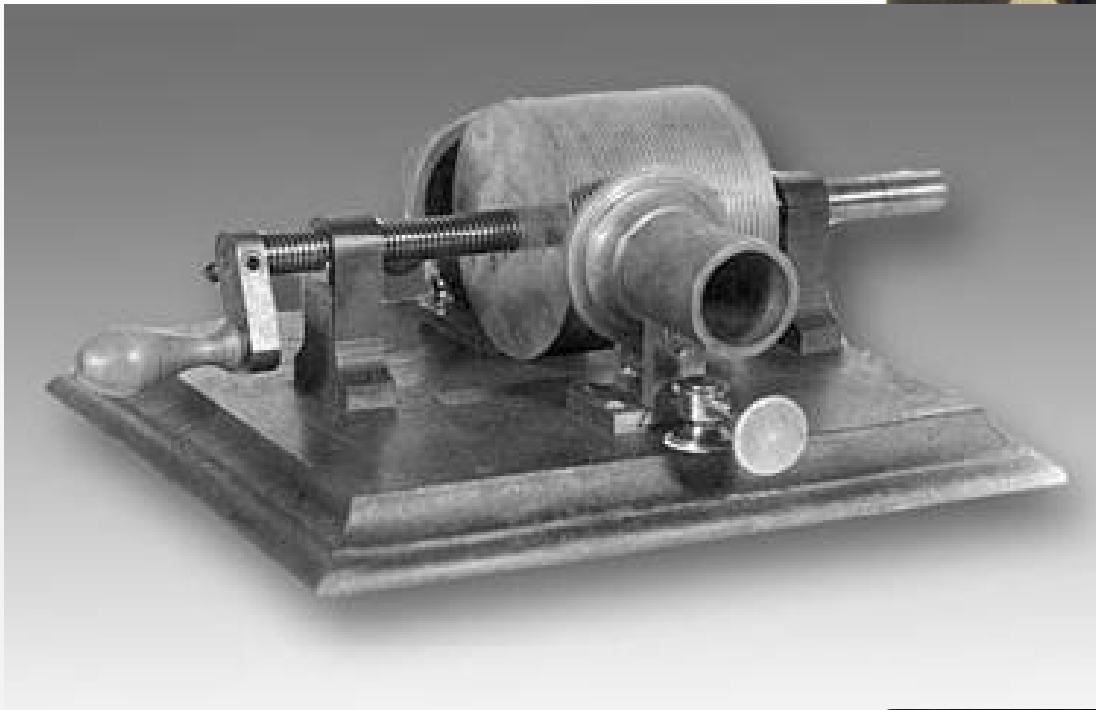
Watch Me Now!
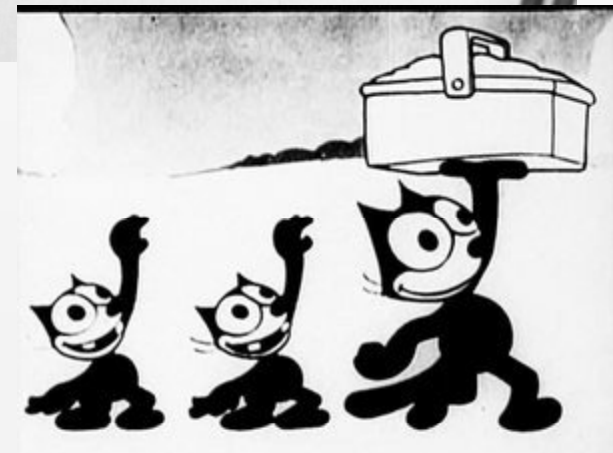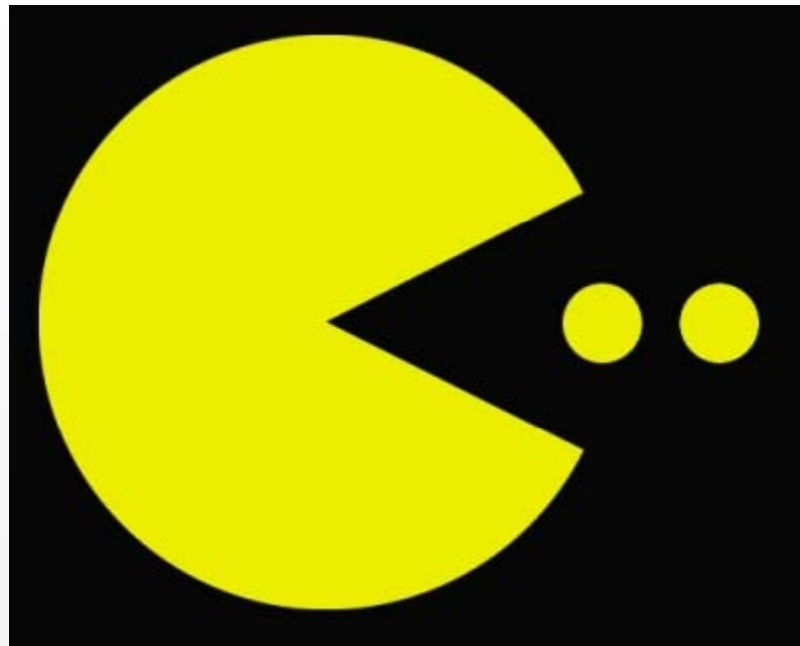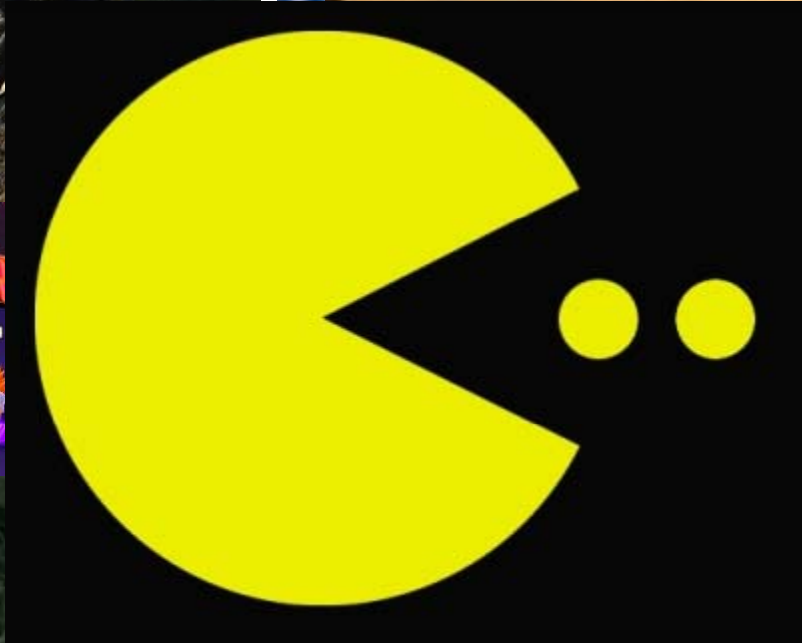
Games Are Mainstream Culture

NVIDIA

**Charts That Look
Like PacMan**

Charts That Do Not Look
Like PacMan
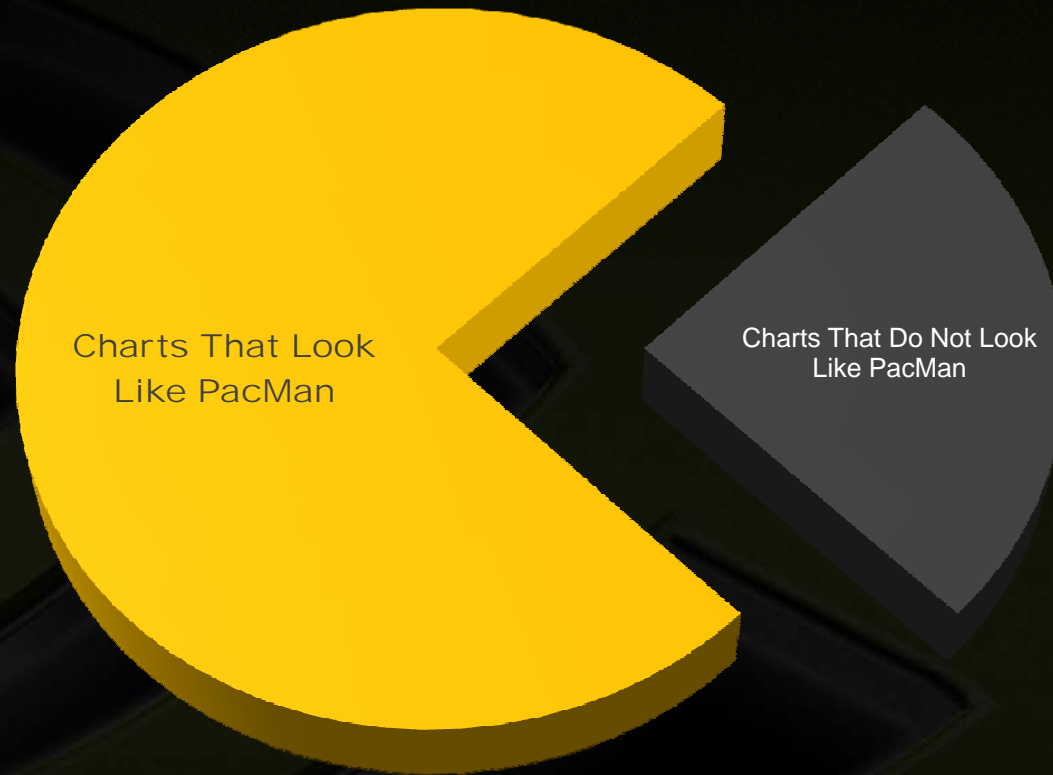
wherez my master sord
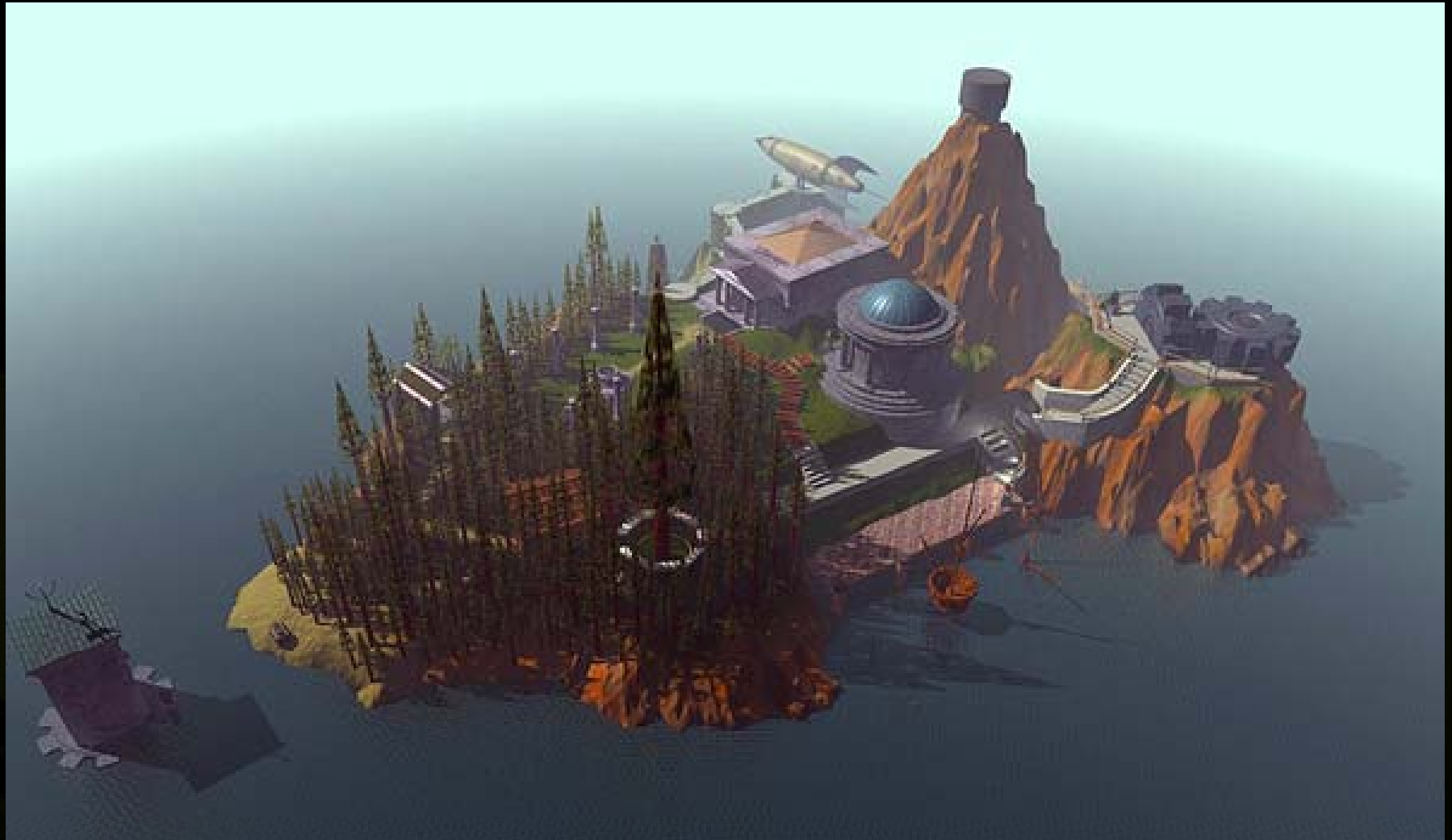
The Importance
Of Beauty

Mehrabian's Rule: 7-38-55
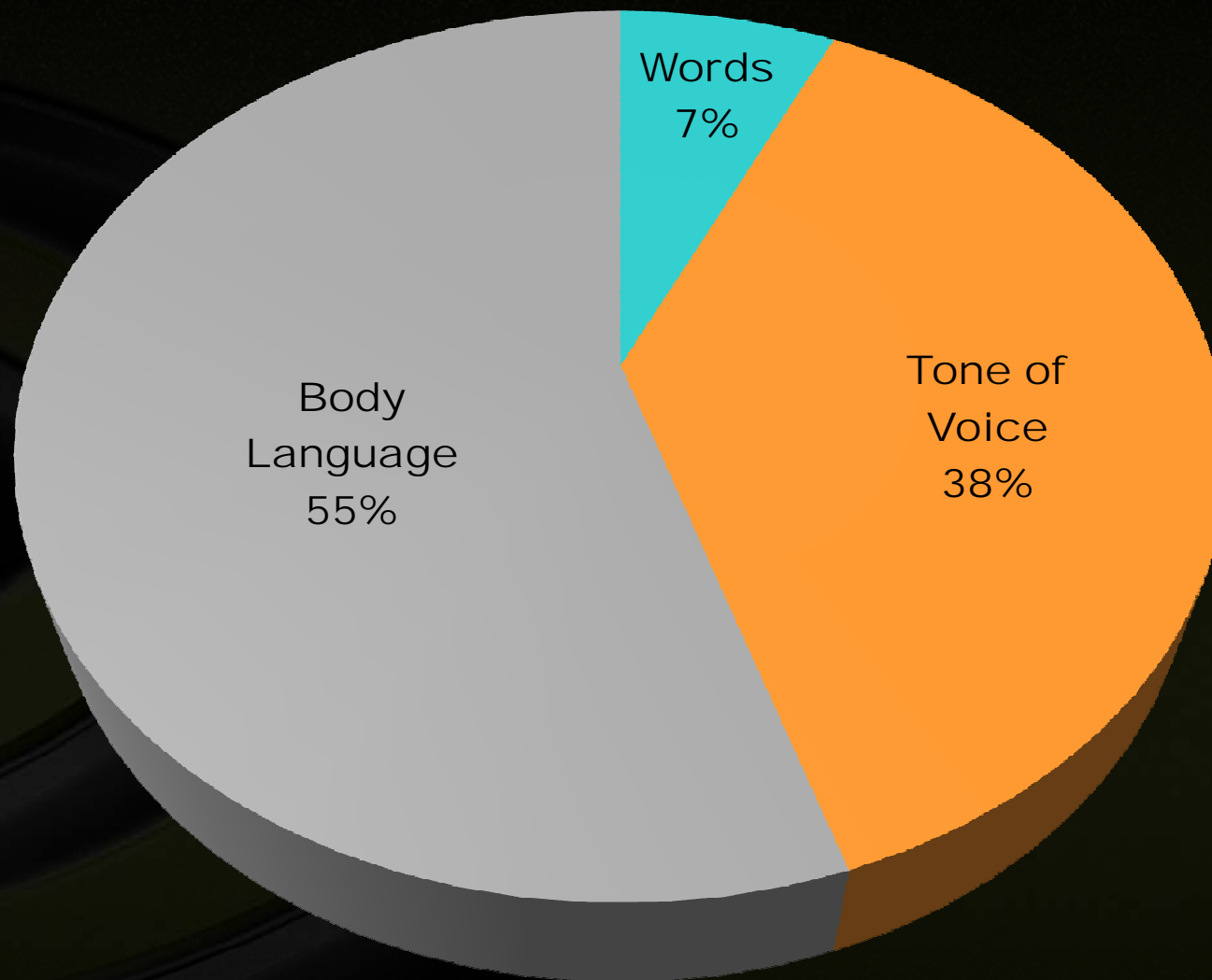
Image: Dee Dee Deepdene

Characters with Character

©2008 Krishnamurti Costa

© NVIDIA Corporation 2008

Characters with Character

"The intention was to make people wonder who was this person, where was she living and when those pictures were taken. All fantasy, of course because this person does not exist at all."

Krishnamurti Costa

http://www.antropus.com/

Which Genres Benefit Most?

- Sports
- Virtual Worlds & MMOs
- Music & Rhythm
- RTS
- Serious Games
- Cut-Scenes and Picture-in-Picture
- What About Combat Games?

Image: Phedre Dumouriez

Changing Expectations

Baked Lighting   Vertex Lighting   Per-Pixel Lighting

Unreal Engine

1   2   3

Physically-Based vs Ad-Hoc

- **Tough calls**
  - **Accuracy is easy to measure, easy to understand**
  - **Control for Entertainment Value**
  - **What is "accurate" about a 30-foot-tall speaking sea creature with a beard?**

**Focus on the Experience,
Rather than the Technology**

Image: Kean Kelly

The Sofa, or the Desk?

Image: phil h
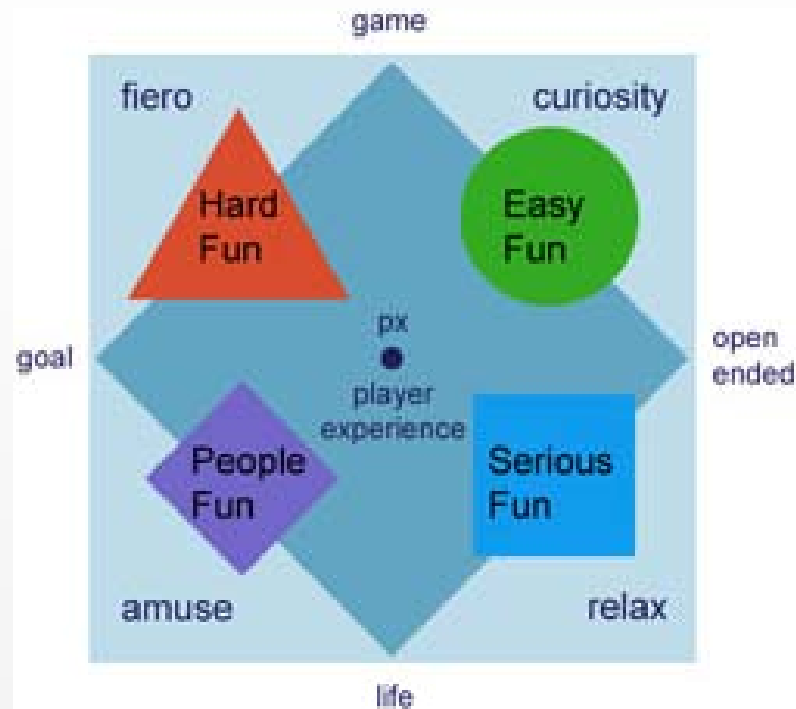
The XeoDesign Chart

The XeoDesign Chart

FPS

Puzzle

Social

RTS

Context Can Override "Content"

Context Can Override "Content"

The Avatar Business:
More than Just 3D Characters

User-Generated Content
Is User-*Specific* Content

POWERED BY
UNREAL
TECHNOLOGY

The Zombie Line

The Zombie Line

Behavior

Appearance

The Zombie Line

Behavior

Appearance

The Zombie Line

The Zombie Line

Behavior

Appearance

© NVIDIA Corporation 2008
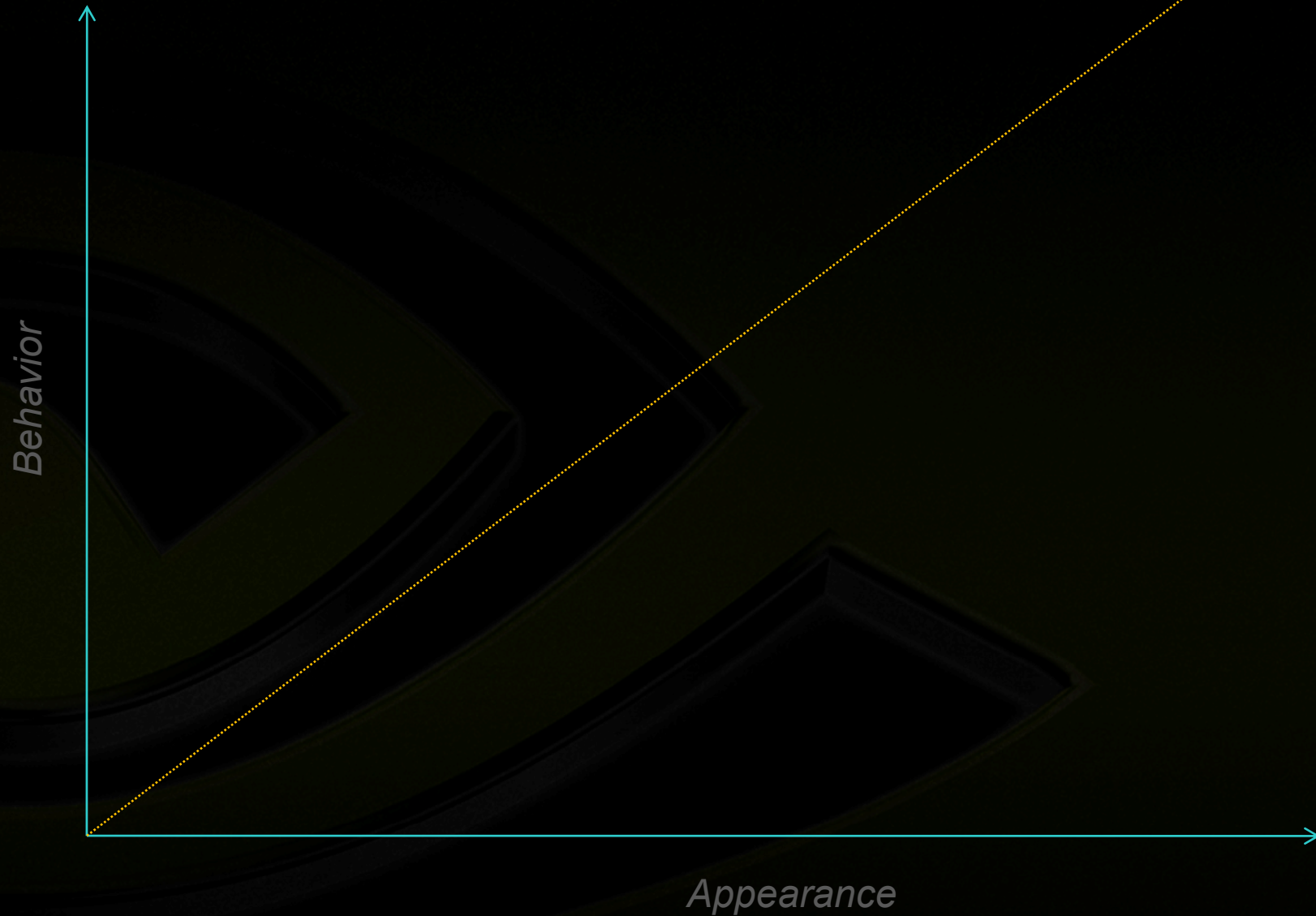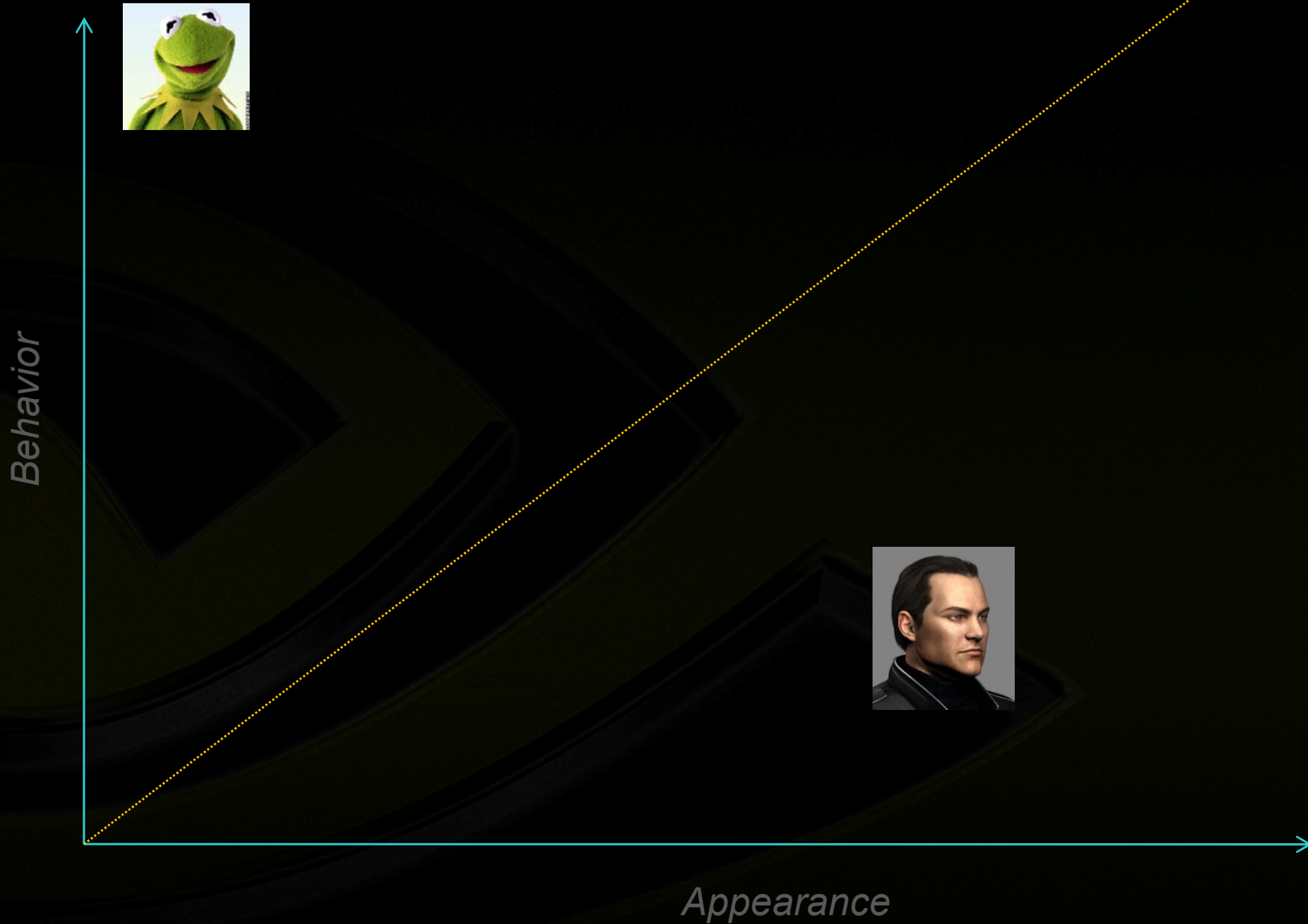
Behavior is Appearance

A Brief Video Interlude...

Appearance & Freedom

Hirata, Mistubuchi, Sueda; 2008
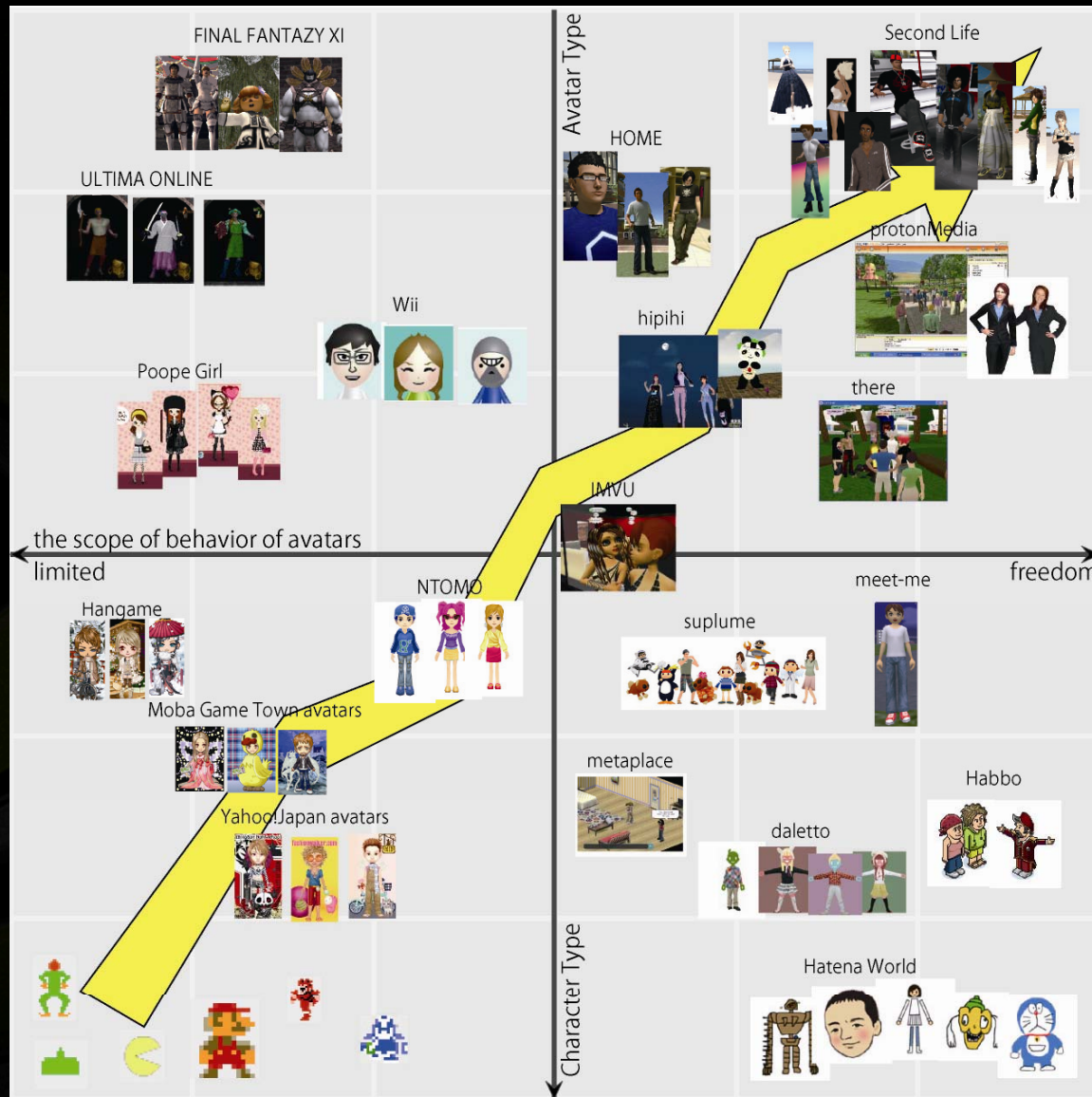
Overlap, Squash & Stretch
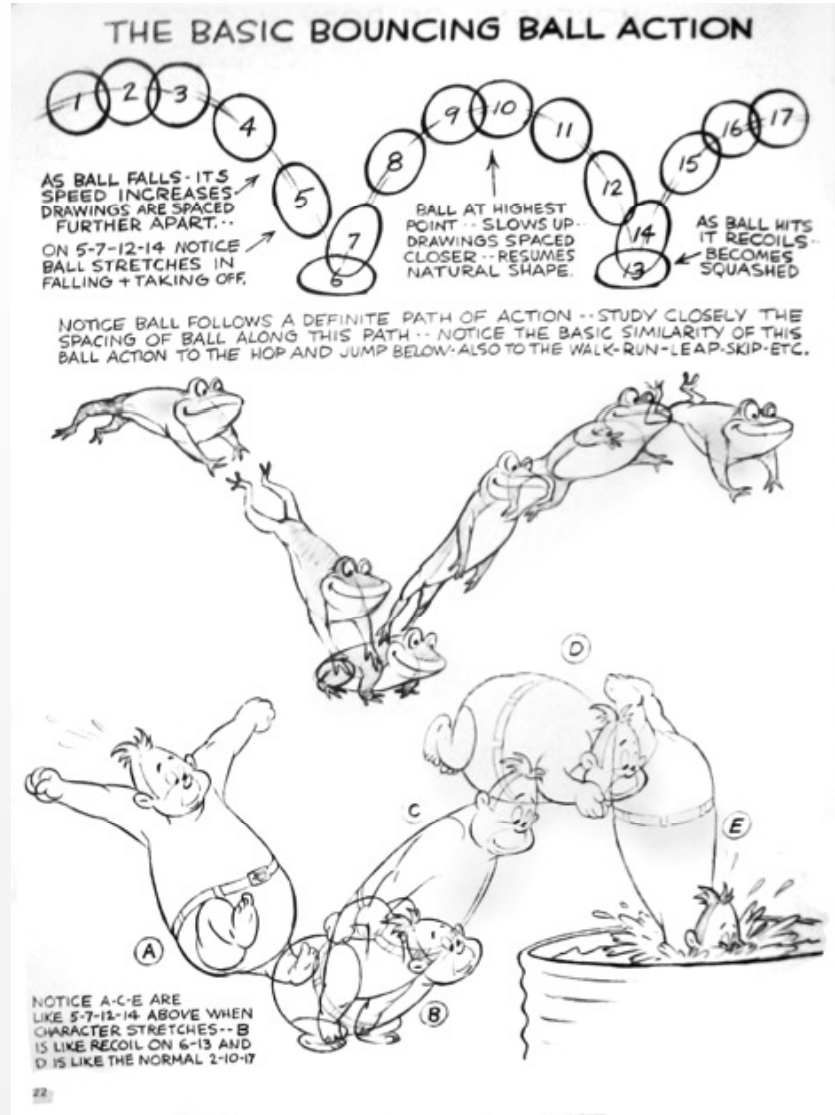
Nurien, Clothing, Follow-through
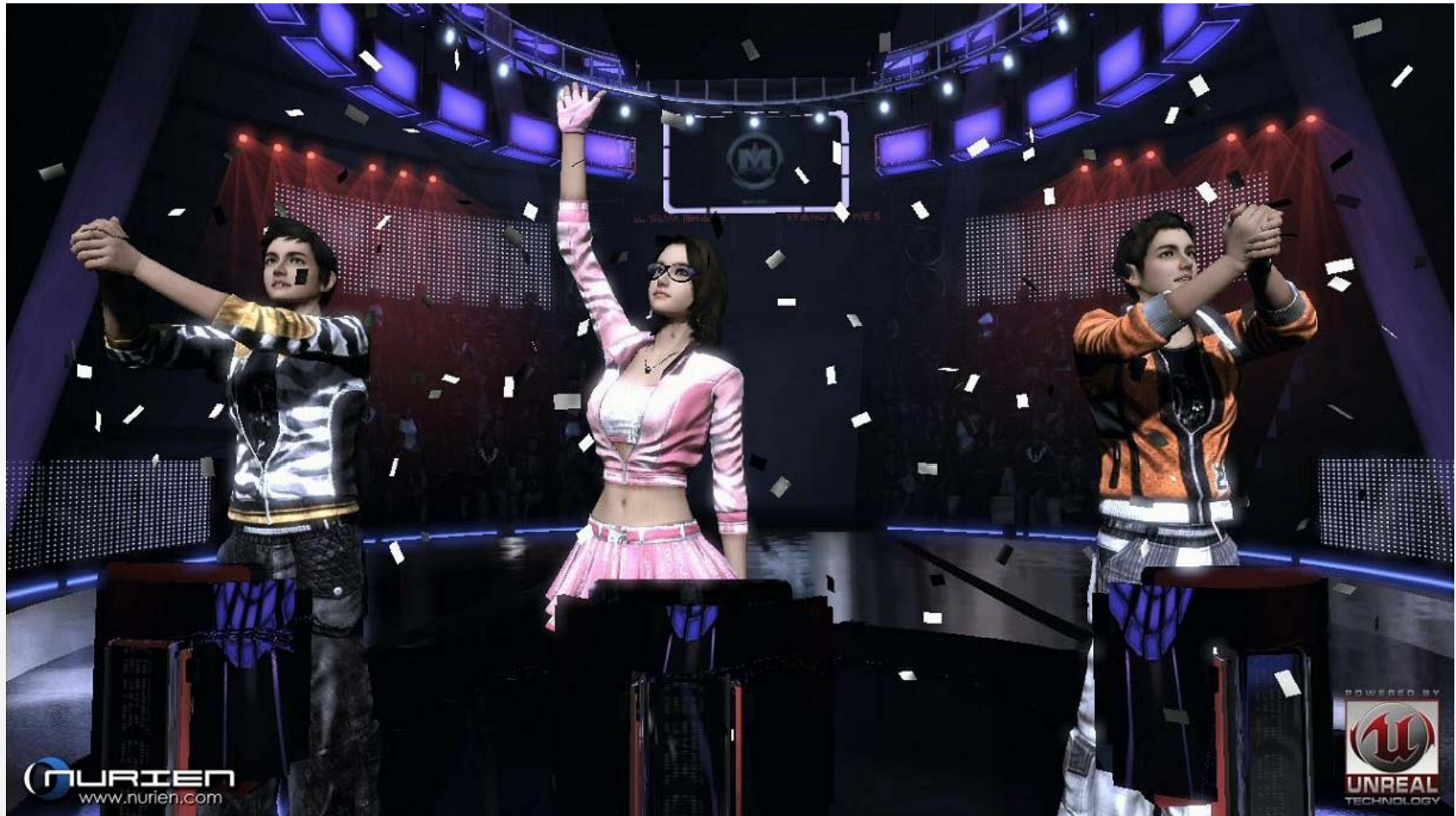
Endless Overlap

Hairstyle

Earrings

Necklace

Clothing
Details

Skirt

Just for Dancers?

"Ying Xiong/Hero," Zhang Yimou; 2002

Just for Dancers?

"Ying Xiong/Hero," Zhang Yimou; 2002
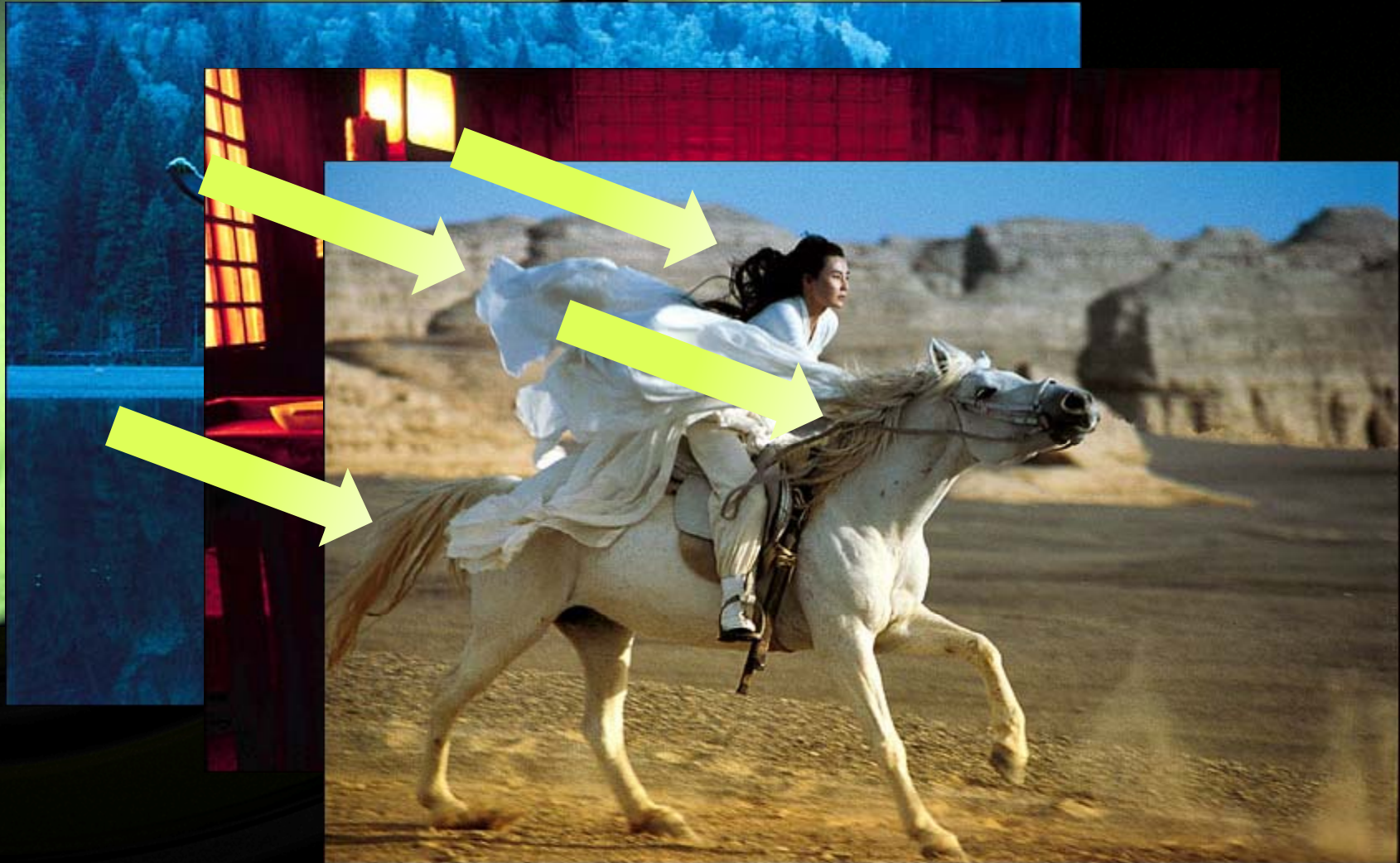
Different Approaches for Different Consumers

Different Regions, Different Toons

- Study showing regional variations
- Not divided ethnically, but stylistically
- Division by age of player
- Average Player Ages, according to a recent PARC study:
  - Maple Story: 18
  - World of Warcraft: 30
  - Second Life: 40

North America

Latin America

Hirata, Mistubuchi, Sueda; 2008

ASIA

OCEANIA

Hirata, Mistubuchi, Sueda; 2008

ICE

Images: F. Paine & Gita Rau

Virtual worlds by sector

Content creation

Socialising/chat

Casual gaming

TV/film/books

Sports

Misc

Education/development

Mirror world

Fashion/lifestyle

Roleplay/fantasy/quests

Music

Toys/real world games

- Konstruction Zone
- 10yrs old+
- Pixie Hollow
- Club Ponypals
- Cars
- Mini-Match
- Spicy Town
- Bunnytown
- Metaplace
- Xivio
- Lively
- Vivaty
- Habbo
- 10 Wagon
- ZooKazoo
- Smallworlds
- Meez
- VizWoz
- Neopets
- IMVU
- Dizzywood
- Tootsville
- 20yrs old+
- Mycosm
- There
- Club Penguin
- Rocketon
- Ourworld
- Seapals
- vMTV
- Activeworlds
- Kaneva
- Smeet
- Papermint
- Whirled
- Multiverse
- HiPiHi
- 30yrs old+
- SL
- Home
- TechDeck Live
- Sportsblox
- Football Superstars
- Empire of Sports
- Qwaq
- Vastpark
- 10yrs old+ 20yrs old+ 30yrs old+ 30yrs old+ 20yrs old+ 10yrs old+
- Geosim
- Kiwi Heroes
- Near
- Twinity
- Handipoints
- Green
- Grockit
- Amazing Worlds
- Jumpstart
- Whyville
- Kraze
- 30yrs old+
- GoSupermodel
- vSide
- Gaia
- Stardoll
- 8D
- Digital Dollhouse
- Worlds (DMC)
- 20yrs old+
- Moshi Monsters
- Lola's Land
- vLES
- FusionFall
- Revnjenz
- Barbie Girls
- Freaky Creatures
- Lego
- 10yrs old+
- Webkinz
- Buildabear
- Hello Kitty
- Ty-girls/Beanie Babies

Legend

- 🔴 Live or open beta
- 🔵 In development/private beta

Virtual worlds by sector

KZERO RESEARCH

Content creation

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10yrs old+
20yrs old+
30yrs old+

Konstruction Zone

Pixie Hollow
Club Ponypals
Cars
Mini-Match
Spicy Town
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10yrs old+   20yrs old+
10yrs old+   20yrs old+   10yrs old+
20yrs old+
10yrs old+

● Live or open beta
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0yrs old+   20yrs old+   10yrs old+

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- 🔵 In development/private beta

All Virtual Worlds
Are driven by fashion

Image: Nedeko Kohime

Image: Dantalion

Skin

Shaders: Copy or Bypass Physics?

"Physically Correct" is useful, possible, and… sometimes not what you want.

Ready for Some Code?

```
// if "adjVal" varies from 0 to 1…..
float LdN = dot(L,N); // lambertian
float newLdN = (LdN+adjVal)/(1.0+adjVal);
float diffuse = max(0,newLdN);
```
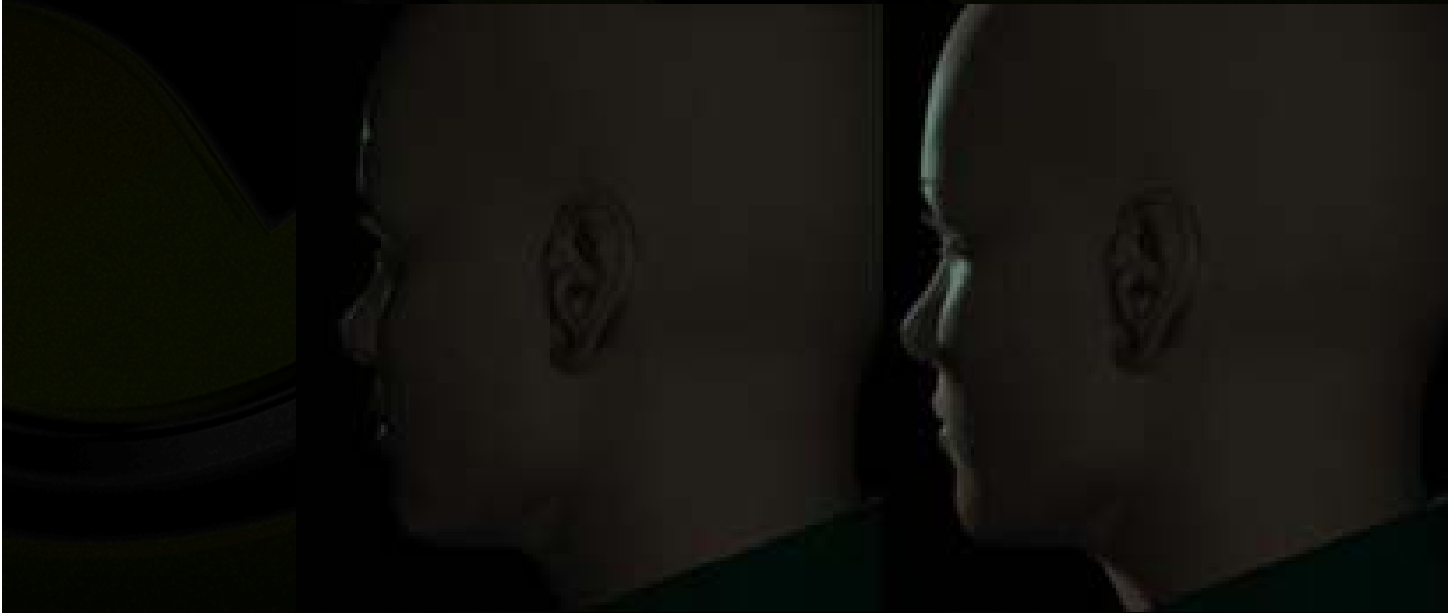
Skin

- **Without shading, it's just so many polygons**

Skin

Without shading, it's just so many polygons

Skin

Without shading, it's just so many polygons

Even in "cartoony" contexts, skin can have a special character
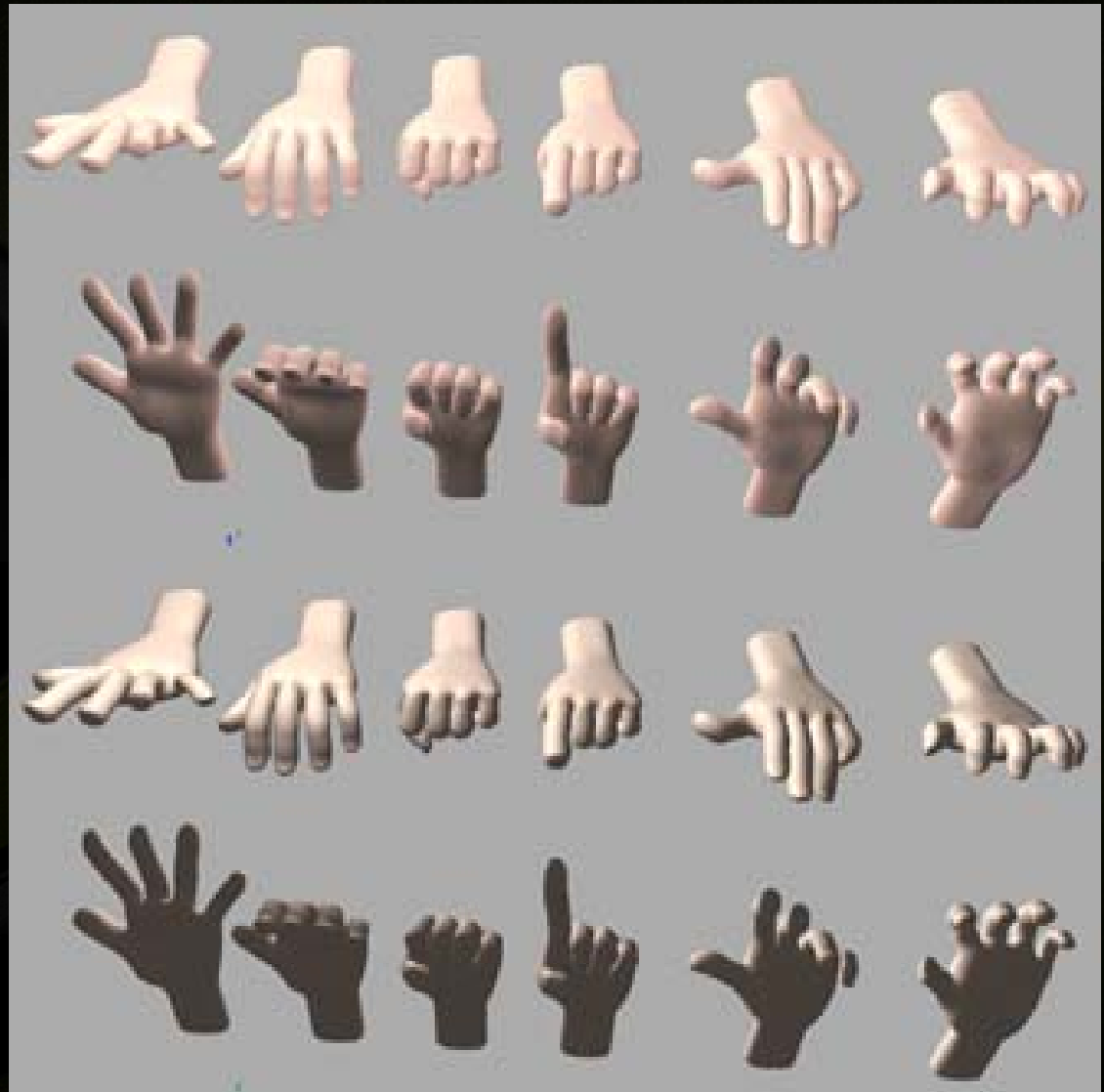
Image: Ina Centaur

Texture-Space Diffusion
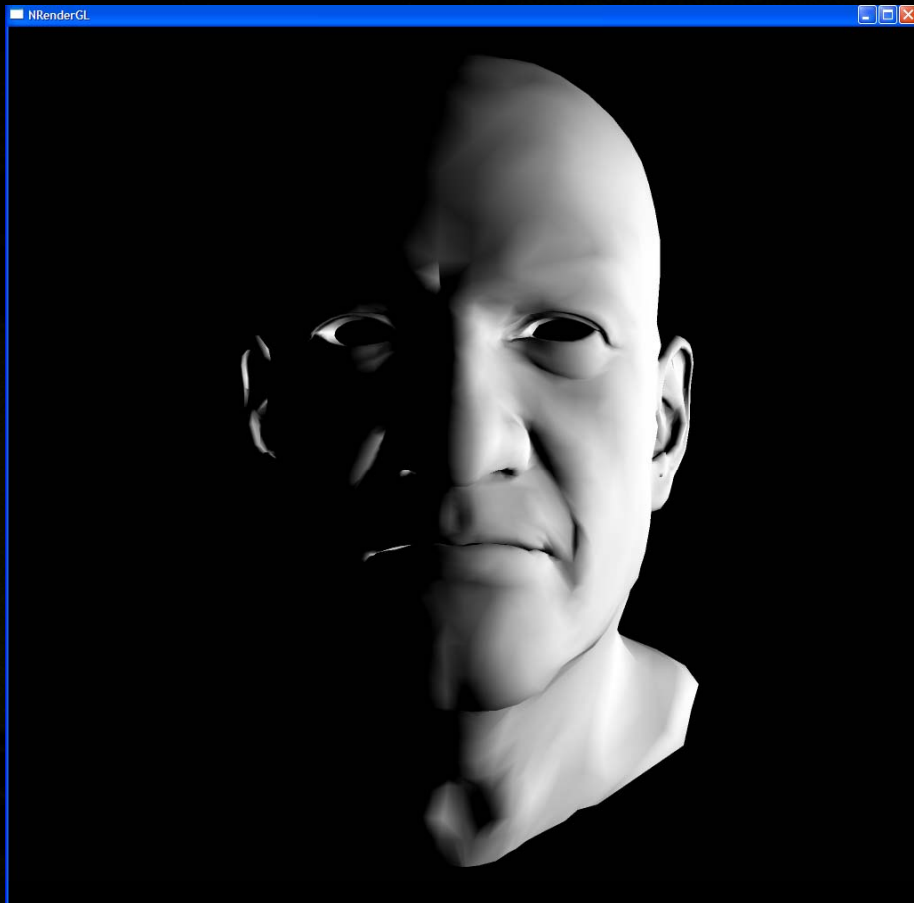
Rendering using texture coordinates

- First, render the surface diffuse lighting into an offscreen texture
- Instead of perspective positions, use surface (U,V)

Blur lit surface texture

- **Now blur**
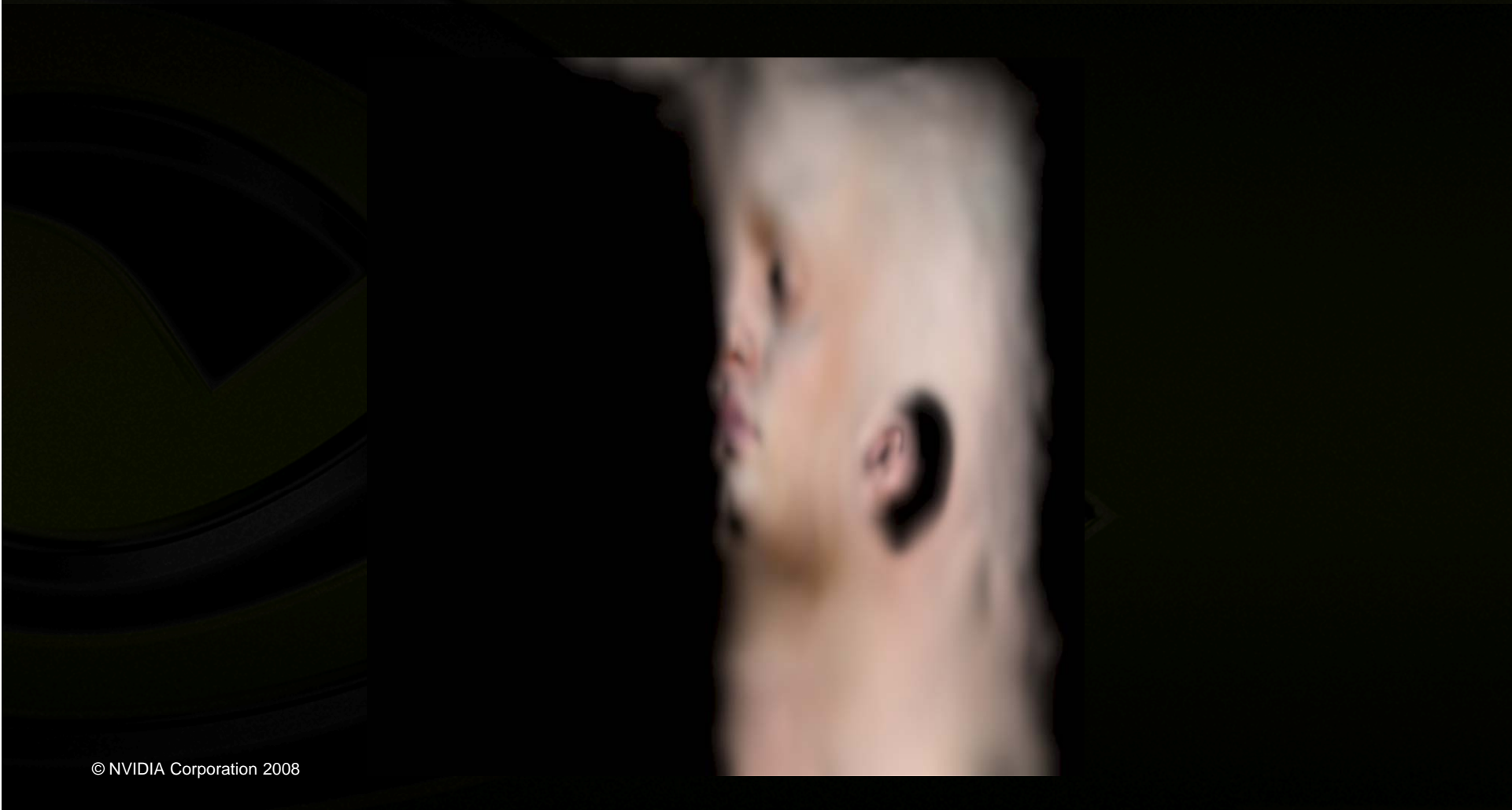
Reapply in perspective

NVIDIA.

- Variations of unlit blur texture shown here

*Scan data courtesy of XYZRGB Inc.

Combine with "straight" lighting

- "Straight" and blurred diffuse are multiplied, while specular is added

The Mix Term

- **For a mix value m (typically between 0 and 1)**
  - $(a^m * a^{(1.0-m)}) = a$
    - **(e.g. for $m=0.5$, a^m is $\sqrt{a}$ so $\sqrt{a} * \sqrt{a} = a$ no surprise!)**
- **We generalize (and take liberties) for our blending:**
  - $D = diffuse\ lighting$
  - $S = specular\ lighting$
  - $Final\_Color = (D^{(1.0-m)} * blurred(D^m)) + S$
- **For Adrienne, m was around 0.82**
- **Extra considerations covered in _GPU Gems 3_**
  - **Varying blur for different colors (hint: red scatters more)**
  - **Avoiding UV distortion**
  - **Object seams**
  - **Getting gamma right**

New Tricks for Old Pixies
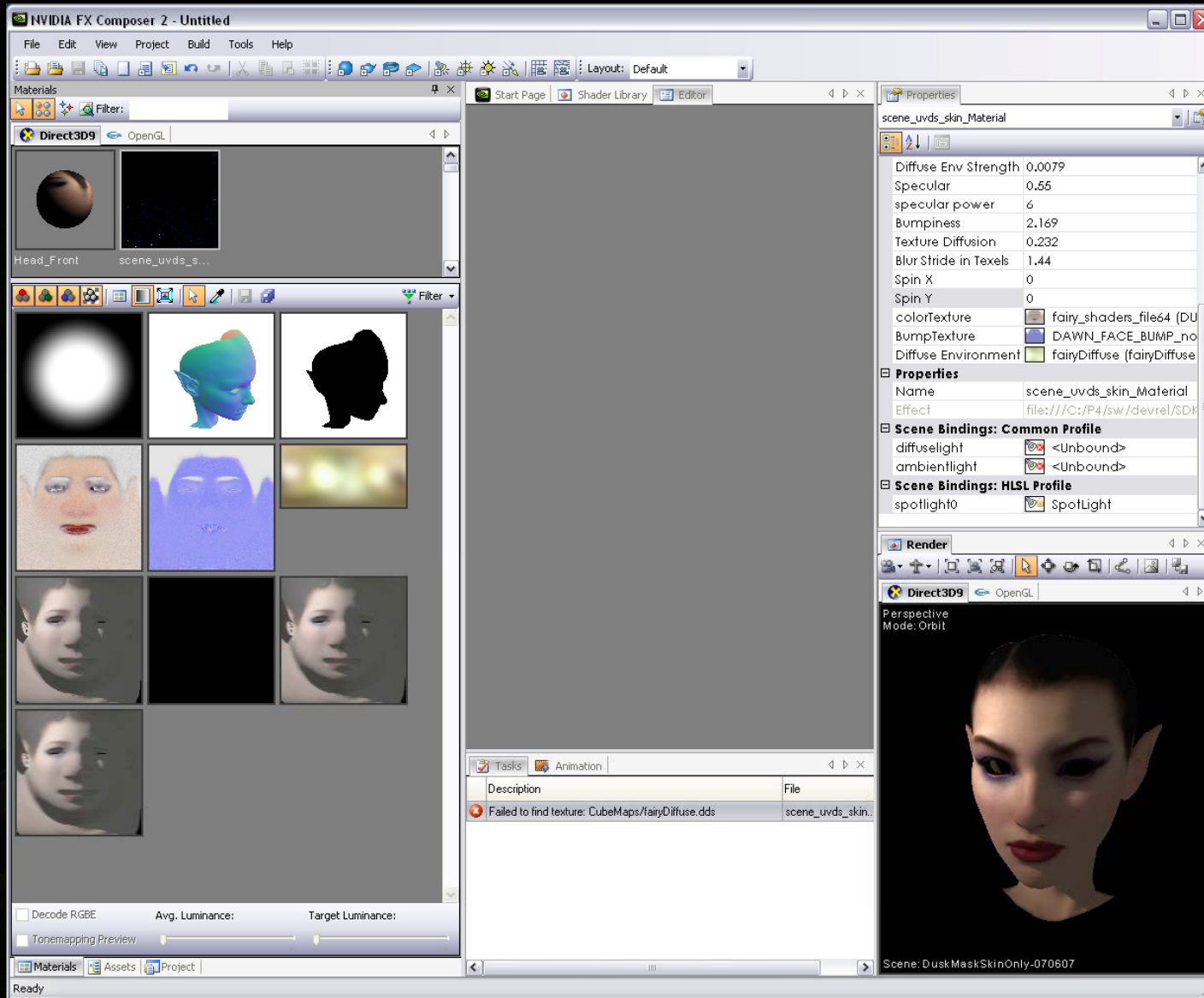
Playable Universal Capture

George Borshukov, John Hable, Jefferson Montgomery, Witek Werner

Electronic Arts

Softimage FaceRobot
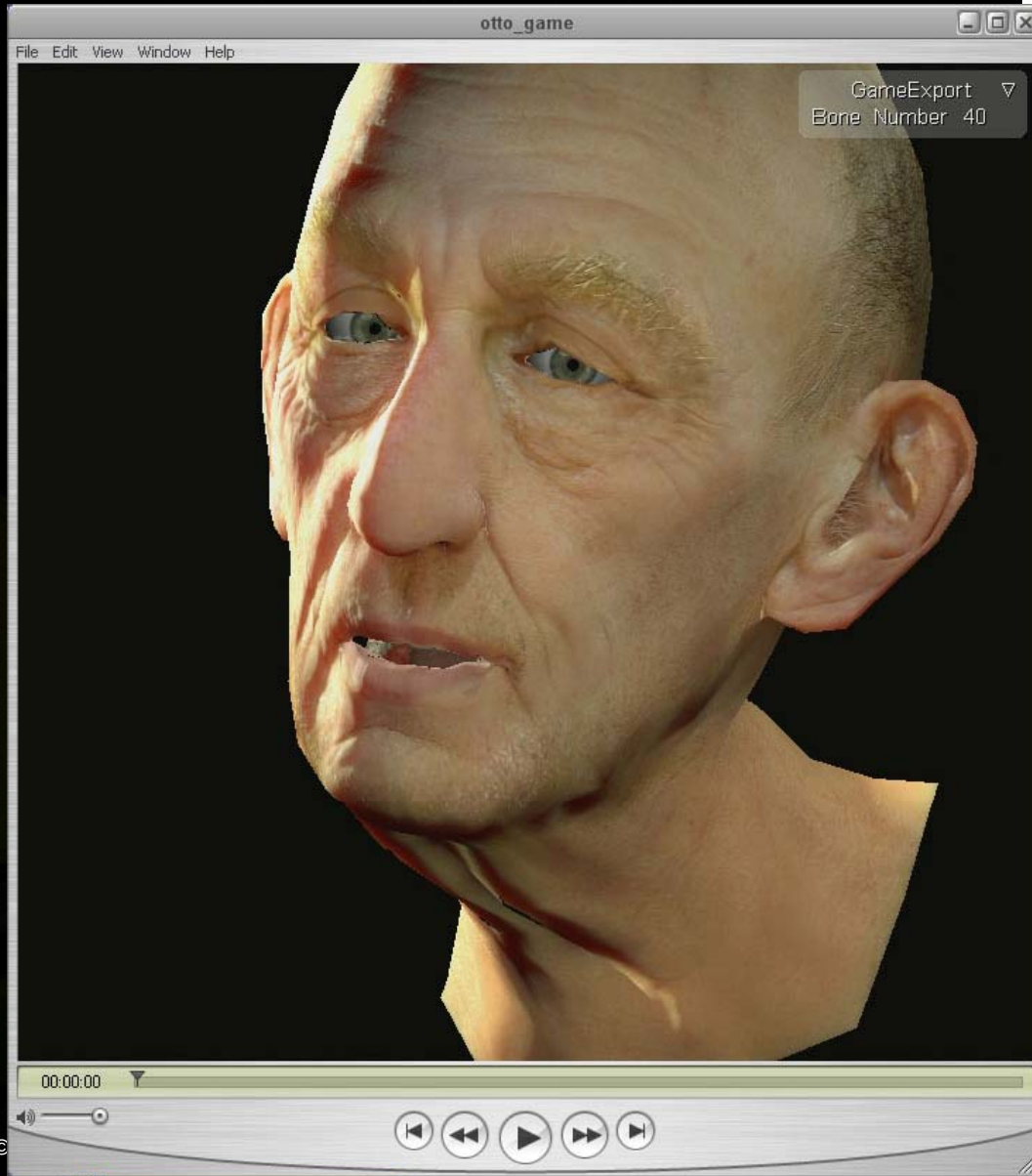
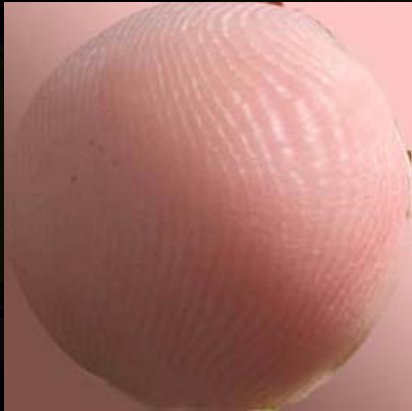**Another Brief Video Interlude...**

Super-Cheap Skin (by accident)
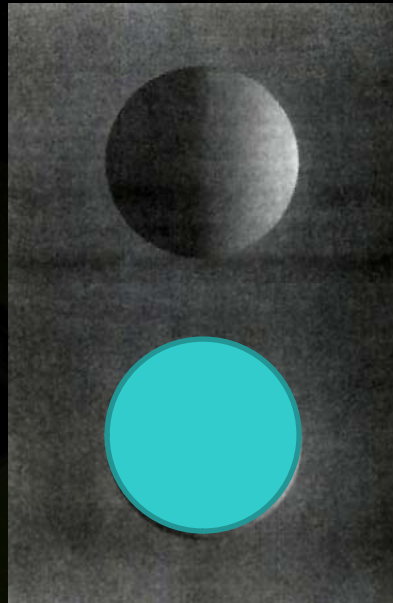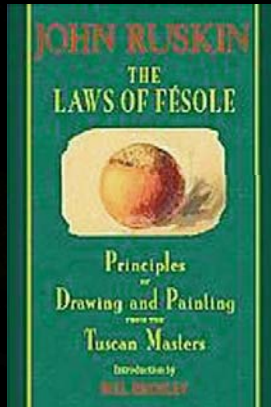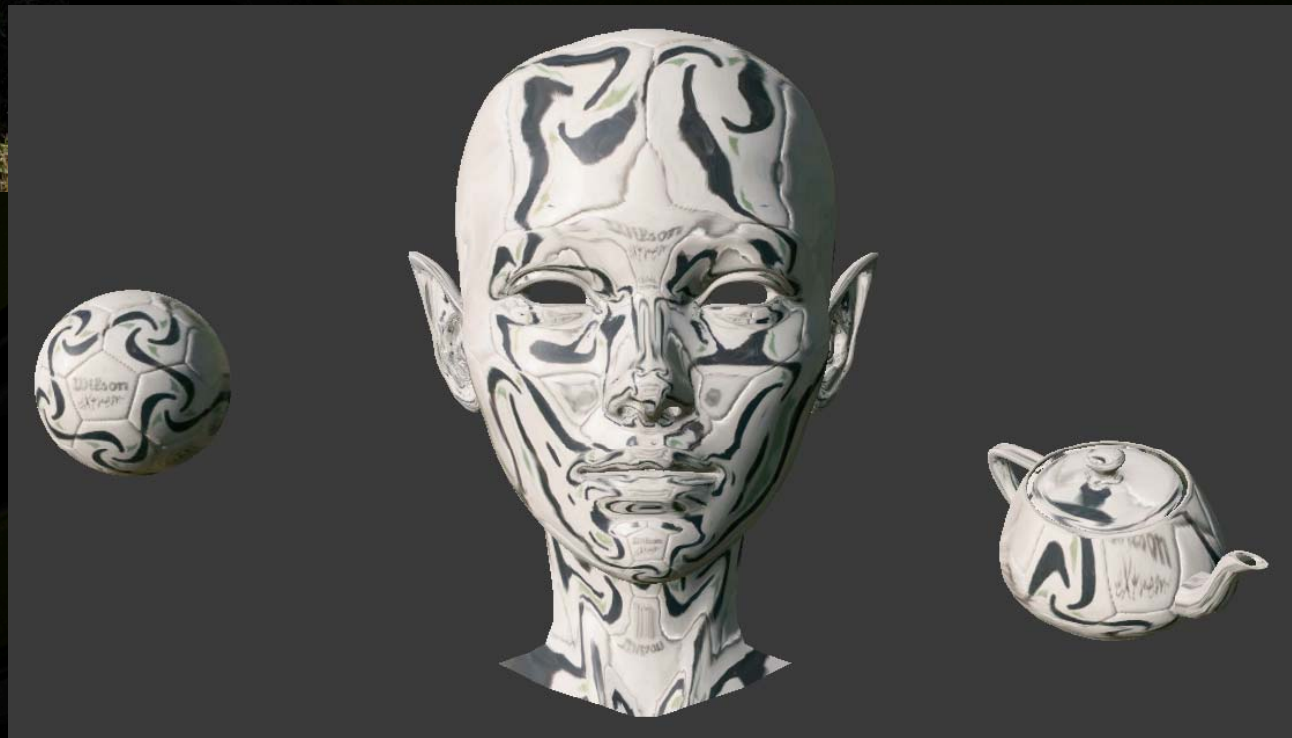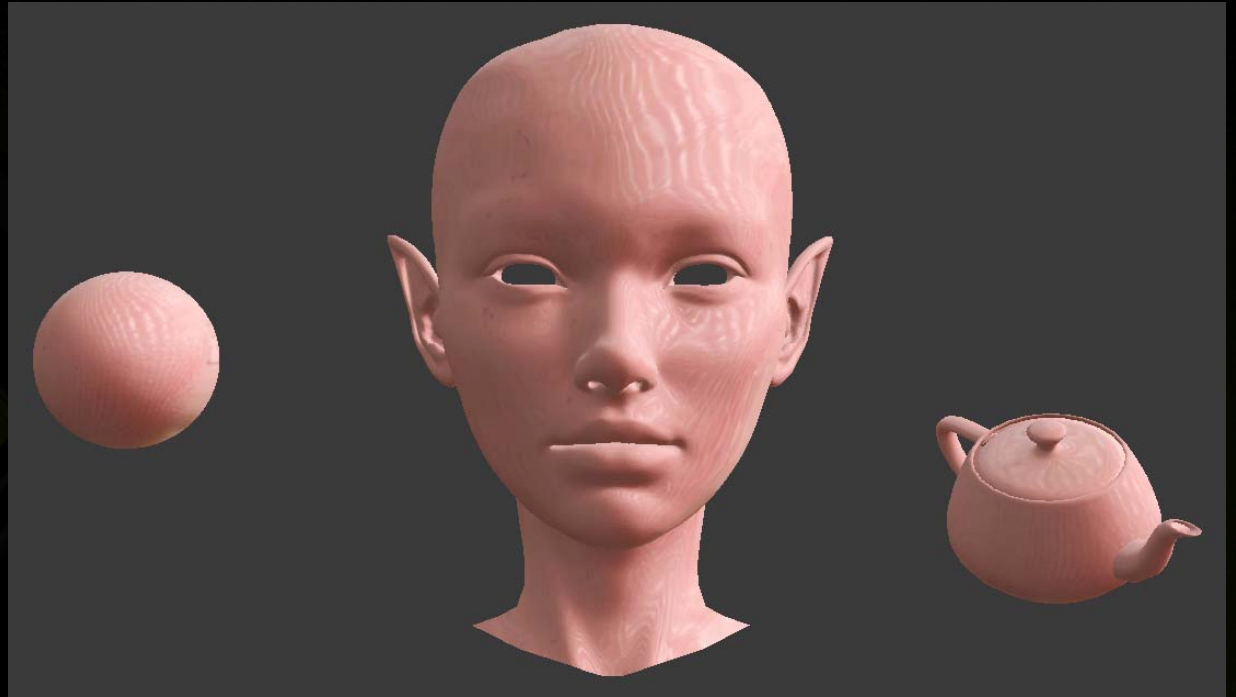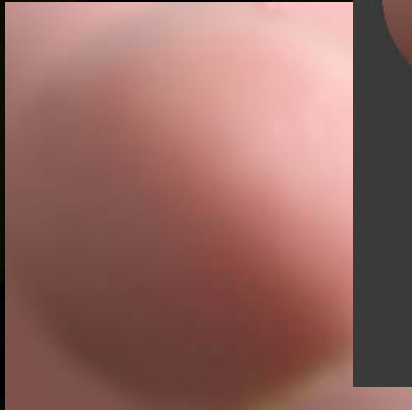
Image: Alexia Meili

Color Manipulations


```
newColor.r = tex1D(cTex,origColor.r).r;
newColor.g = tex1D(cTex,origColor.g).g;
newColor.b = tex1D(cTex,origColor.b).b;
```

Shadows

Shadows

Second Life

Unreal Engine
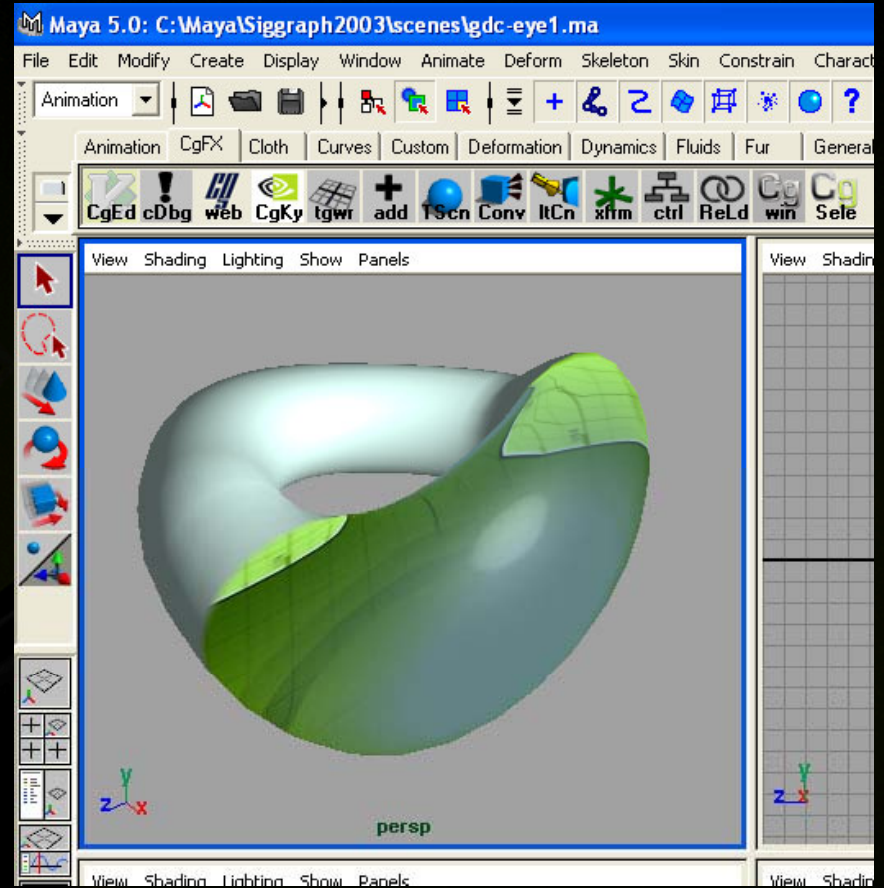
© NVIDIA Corporation 2008
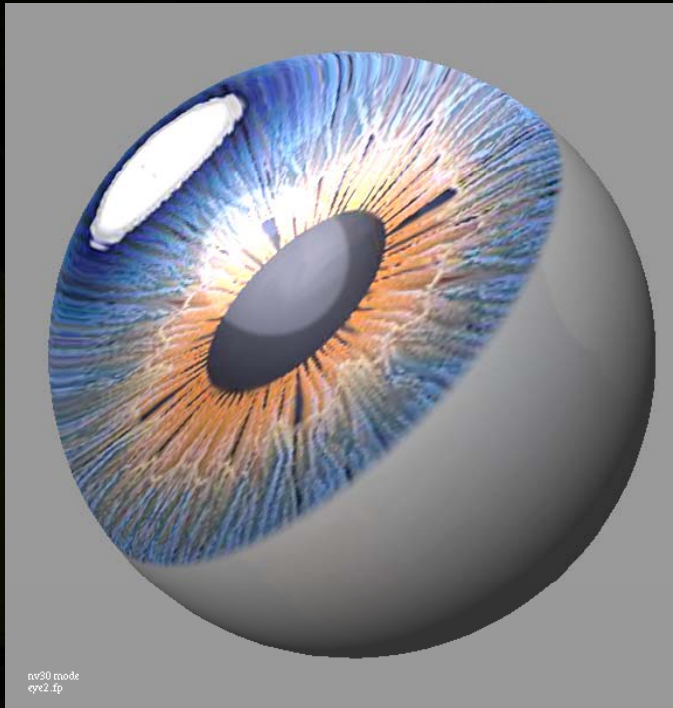
Caravaggio's Helper: Roberto Rizzato

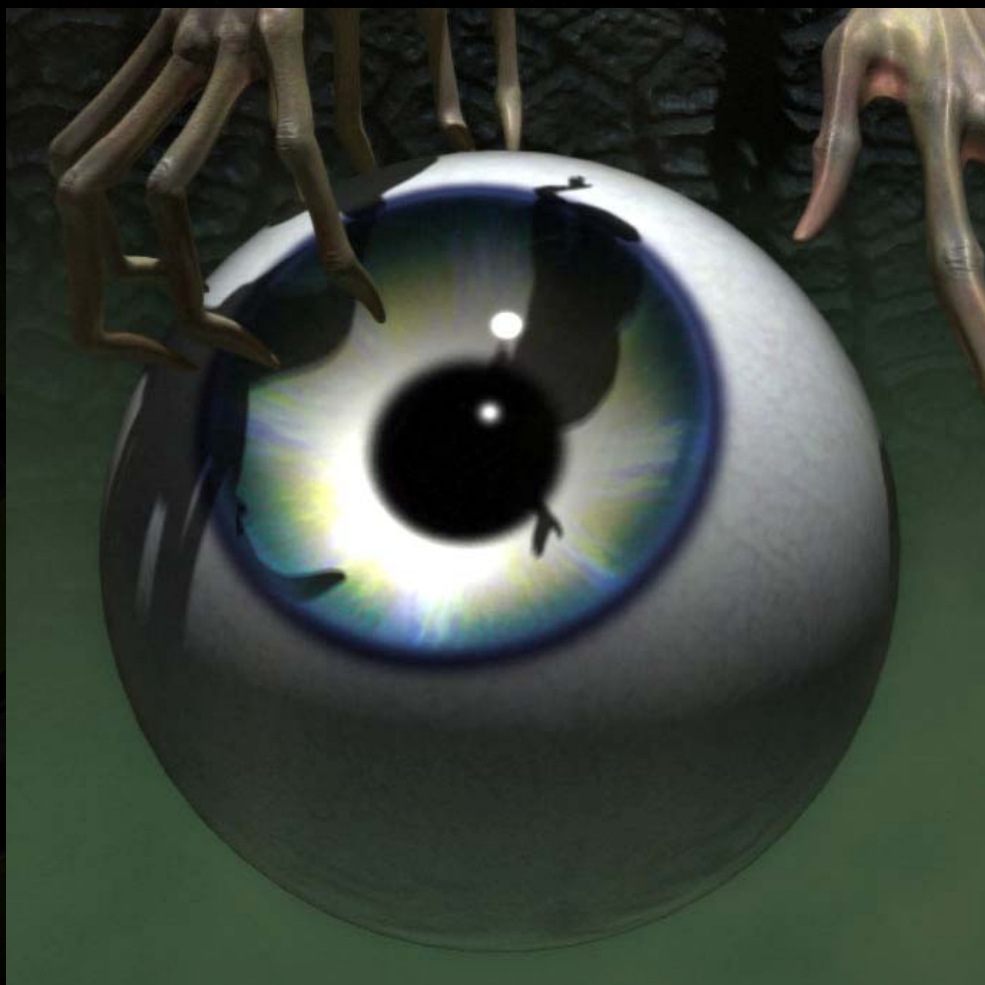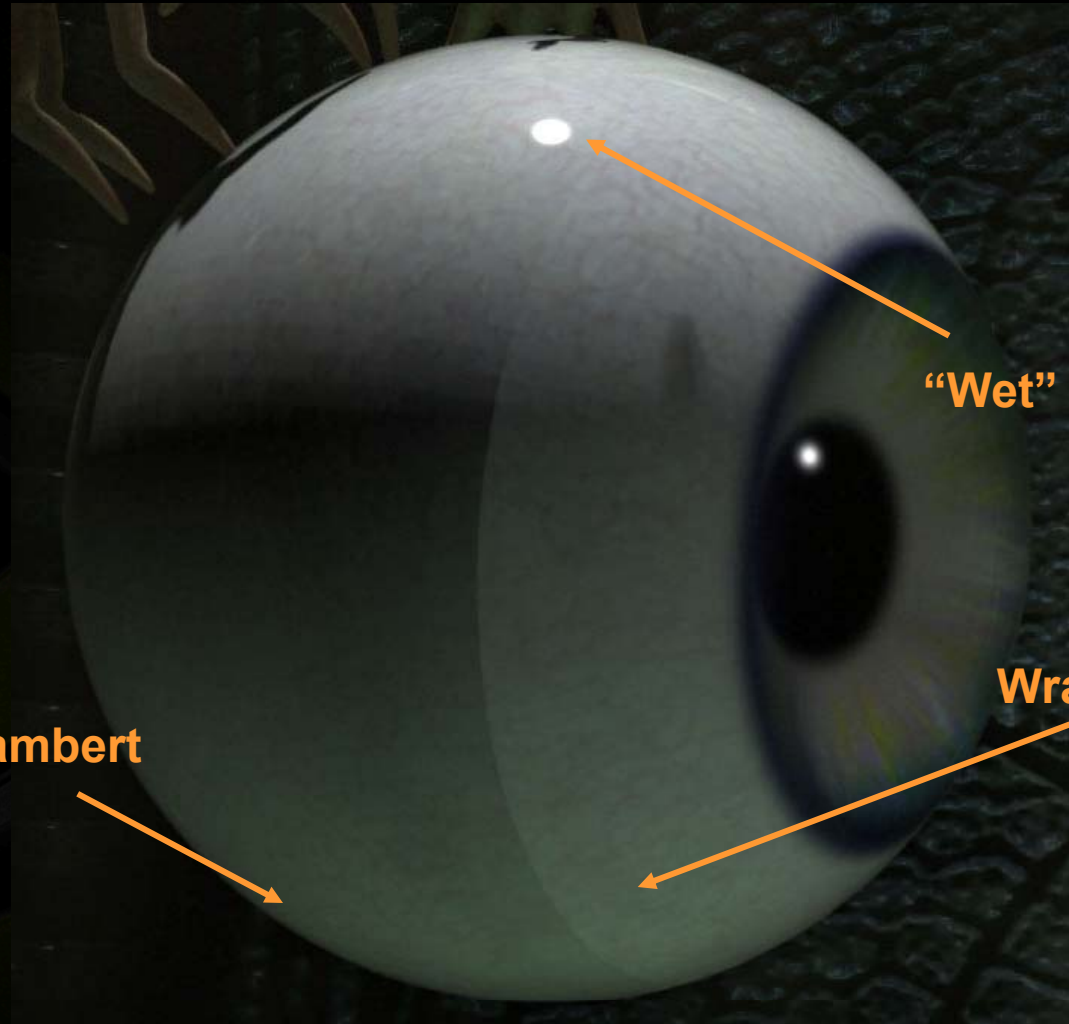# Realism is a Tactic, Not a Goal

A Thing of Beauty

Making Better Eyes

"Wet" highlight

Wrap-lighting of 0.2
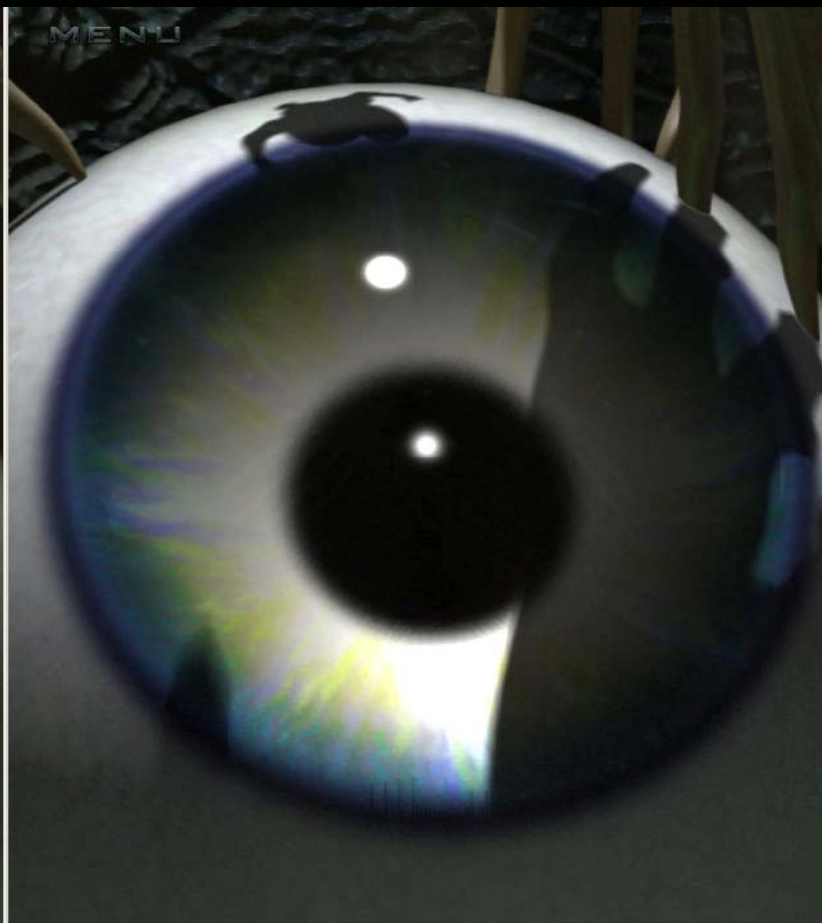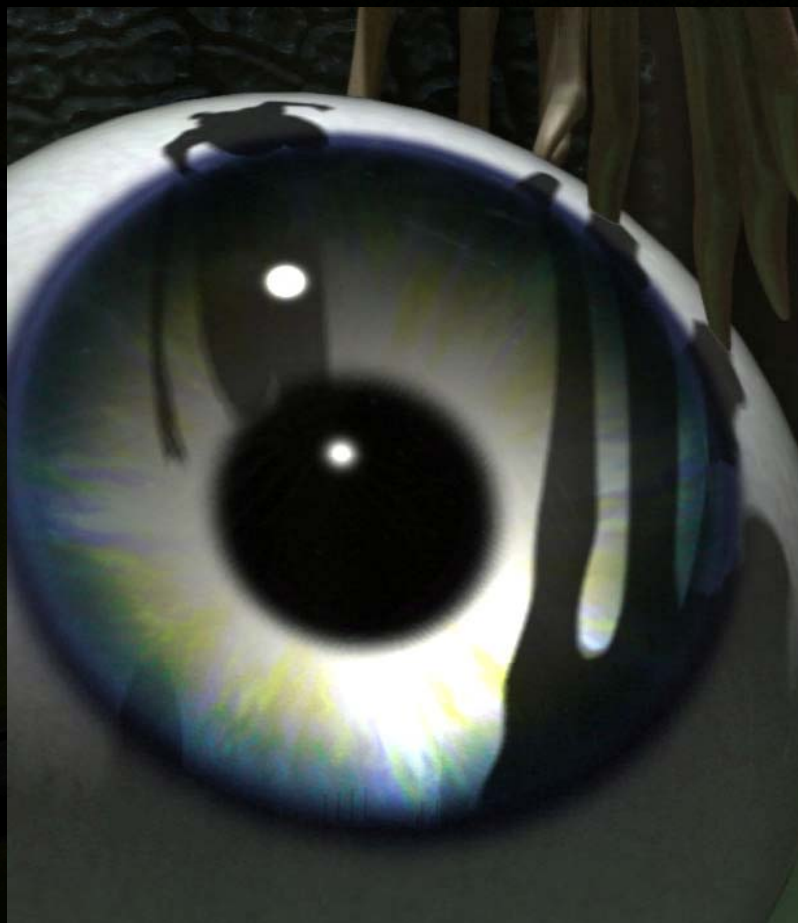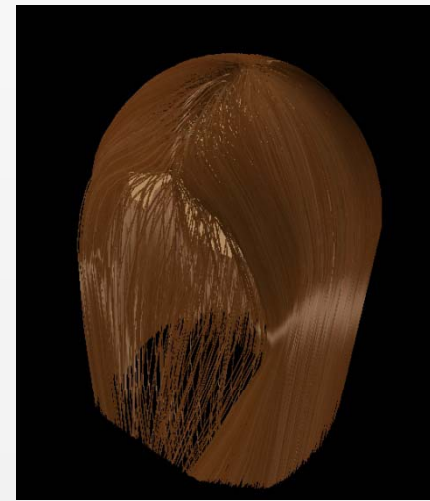
Standard Lambert
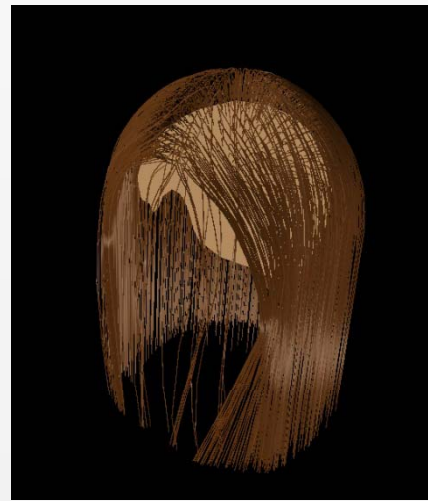
Plus: bent shadows

Image: Mia Olivier

Hair Research

- Aki Ross' hair consumed up to 25% of *ALL* computing resources in *Final Fantasy (2001)*
- Fortunately, hairs are parallel!

Our Latest Results

- 166 simulated strands
- 0.99 Million triangles

- Stationary: 64 fps
- Moving: 41 fps

- 8800GTX, 1920x1200
- 8XMSAA

More Latest Results

- **166 simulated strands**
- **2.1Million triangles**

- **24fps**

- **8800GTX, 1280x1024**
- **8xMSAA**
- **2xSSAA with 5 taps**

Demo Time….

Toggle REF (F3)

Change device (F2)

Reset Simulation (F4)

Scene

- [X] shadows
- [X] simulate
- [X] integrate
- [X] addGravity
- [X] curlyHair
- [X] add forces
- [X] linear stiffness
- [X] body collisions
- [ ] inter-hair collisions
- [ ] render hair density

PCF Absorption: 8.00

Num simulation Iterations: 10

Density Threshold for interhair: 10.2

Angular stiffness multiplier: 1.00

Wind Strength: 0.21

Gravity Strength: 0.50

Inter-hair force strength: 0.000

- [X] use blurred density

Gaussian

Blur Radius: 5

Blur Sigma: 4.00

http://developer.nvidia.com/object/siggraph-2008-hair.html

Shading: Kajiya and Kay

- **Kajiya and Kay** *[Rendering fur with three dimensional textures (SIGGRAPH '89)]*

- **Diffuse = sin(T,L) = sqrt(1 – T . L^2)**
  Specular = [T . L * T . E + sin(T,L) sin(T,E)] ^{p}
  = [T . L * T . E + sqrt(1 – T . L^2) sqrt(1 – T . E^2)] ^{p}

- **Ivan 2006**
- **fake dual specular highlights**
  - primary highlight shifted towards tip
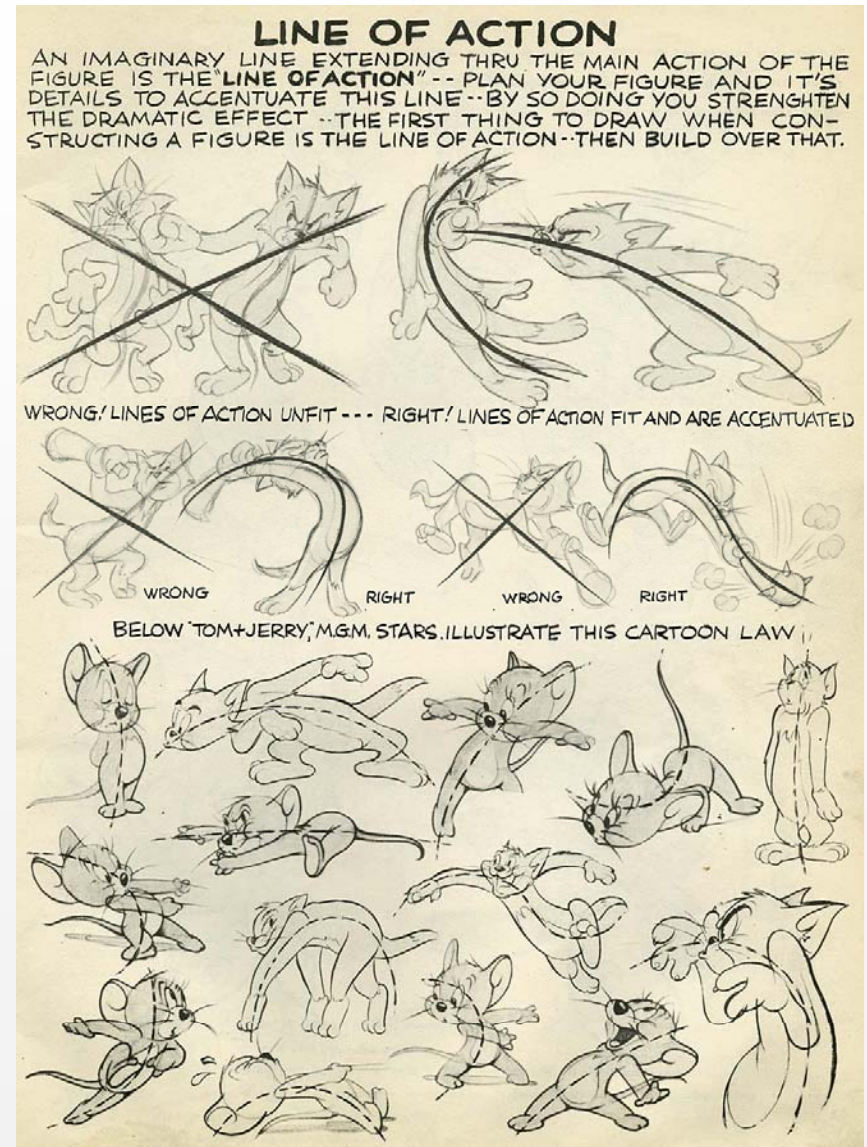 - secondary highlight shifted towards root
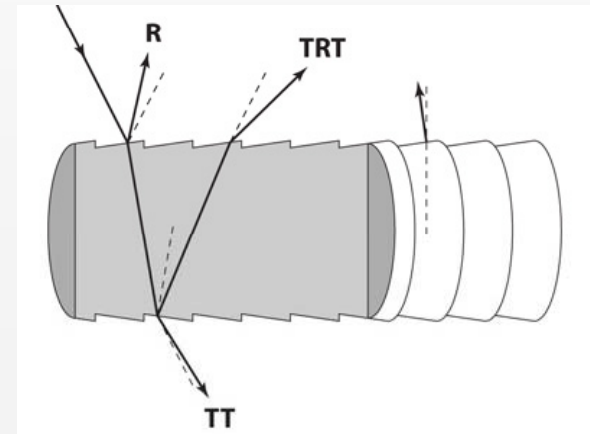
"Ivan" model emulates
Marchner "R" & "TRT" terms

Animation Challenges

- *Precise* control is not always easy
  - Physically-Based
  - Wiggly Splines etc
- 3D "Line of Force" instead of a screen-space arc?
- Balance noodling against productivity!
- Some animators can tear hair, clothes, etc
  - "Classical" animators may be used to strong one-frame moves that would result in huge force!

LINE OF ACTION
AN IMAGINARY LINE EXTENDING THRU THE MAIN ACTION OF THE FIGURE IS THE "LINE OF ACTION" -- PLAN YOUR FIGURE AND IT'S DETAILS TO ACCENTUATE THIS LINE -- BY SO DOING YOU STRENGHTEN THE DRAMATIC EFFECT -- THE FIRST THING TO DRAW WHEN CONSTRUCTING A FIGURE IS THE LINE OF ACTION -- THEN BUILD OVER THAT.

WRONG! LINES OF ACTION UNFIT --- RIGHT! LINES OF ACTION FIT AND ARE ACCENTUATED

WRONG   RIGHT   WRONG   RIGHT

BELOW TOM+JERRY, M.G.M. STARS, ILLUSTRATE THIS CARTOON LAW

Similar Objects/Phenomena

- Regardless of the control scheme, consider:
  - Grass
  - Manes
  - Tails
  - Jungles
  - Undersea

Image: Toko Voom
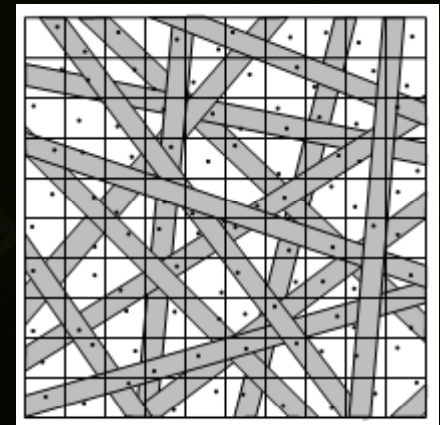
- **High Frequency**
  - **Shadow volumes are impractical**
  - **Shadow mapping has aliasing issues: spatial and mostly temporal (flickering)**

- Transparency
  - Because hair can be translucent, especially blond hair
  - But mainly because hair is so thin that it never covers a full pixel

Possible Shadowing Techniques

NVIDIA.

- **Regular Shadows**
  - **Percentage Closer Filtering (PCF)**
  - **Convolution Shadow Maps (CSM)**

- **Deep Shadows**
  - **Deep Shadow Maps (DSM)**
  - **Opacity Shadow Maps (OSM)**
  - **Multi-Layer PCF**
  - **Absorption-weighted PCF**

Regular PCF

- **Parameters**
  - **Resolution of the shadow map**
    - **512^2 can be good enough when using a large number of PCF taps**
  - **Number of PCF taps / pixel**
    - **Perfectly hard shadows on hair do not look good, so we want to use filtering anyway**

D3D10 165.09 fps Vsync off (800x600), R8G8B8A8_UNORM (MS4, Q16)
HARDWARE: NVIDIA GeForce 8800 GTX

NVIDIA.

Toggle full screen
Toggle REF (F3)
Change device (F2)

NumTris: 678612

LightRes: 512x512

MultiLayerPCF

Opacity: 1.00

Num layers: 1

© NVIDIA Corporation 2008

D3D10 69.19 fps Vsync off (800x600), R8G8B8A8_UNORM (MS4, Q16)
HARDWARE: NVIDIA GeForce 8800 GTX

NVIDIA.

Toggle full screen
Toggle REF (F3)
Change device (F2)

NumTris: 678612

LightRes: 512x512

MultiLayerPCF ▼

Opacity: 1.00

Num layers: 1

Regular PCF

NVIDIA.

- **Brute-Force PCF filtering**
  - Conceals shadow map aliasing
  - Bonus: soft shadows, which are nicer than hard shadows
  - With a large kernel such as 225 taps / pixel, no depth bias is required

Opacity Shadow Maps

- Considers the hair as a volumetric media of variable density. [Kim and Neumann 01]
- Slices the (accumulated) density function with a fixed number of slices.
- The shadows can be made soft simply by blurring the opacity slices of the OSM.

Issue with OSMs

- Slices are not aligned with the hair geometry, and so OSMs have banding artifacts which move with the light.

- These banding artifacts do not go away by blurring the slices in the x and y directions.

- Banding may go away by blurring in the z direction, but this would introduces significant light bleeding. See next slide.

- **Hair is a case of semi-transparent material. Under this assumption, its transmittance function along a viewing ray looks like this:**

(a)

τ^s
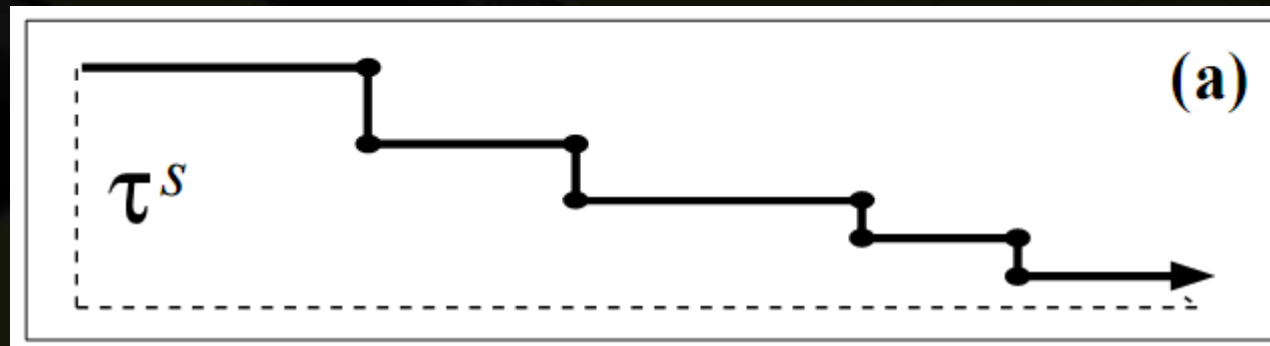
[Lokovic and Veach 2000]

- **Each time a hair is intersected, the transmittance is multiplied by the transparency of the hair.**

GPU Deep Shadow Maps

- Depth peel a fixed number of depth layers from the light's point of view.
- For shadowing:
  - Project the pixel onto the light plane as usual.
  - Initialize T to 1 and multiply T by the transmittances between the light and the pixel. (If the search has a uniform opacity, then this could be reduced to a binary search.)
  - Filter the result of the operation above on multiple texels to reduce aliasing.

DSM vs OSM

- DSMs have no banding problems because they are based on the actual geometry.

- A DSM with 4 layers is usually sufficient for 50%+ opaque hair because after 4 layers, the transmittance is lower than $(50\%)^4 = 6\%$.

- However, if banding artifacts are not a problem, then blurred OSMs may be fine.

Multi-Layer PCF

- **For semi-transparent materials, A DSM with 1 layer is the same as regular PCF**
- **PCF is much more efficient than DSM because it can run 2x2 PCF tests in a single texture fetch.**
- **We modified the DSM algorithm to simply apply PCF on multiple layers of depth.**

Absorption-Weighted PCF

- **To get the deep shadow look without having to actually capture multiple layers of depths or opacities**
- **We assume that the hair is a volume of uniform absorption, and weight our PCF taps by an exp(-sigma.d) function.**

D3D10 60.55 fps Vsync off (800x600), R8G8B8A8_UNORM (MS4, Q16)
HARDWARE: NVIDIA GeForce 8800 GTX

Toggle full screen
Toggle REF (F3)
Change device (F2)

NumTris: 678612

LightRes: 512x512

AbsorptionPCF

Opacity: 0.04

© NVIDIA Corporation 2008

Image: Iceykara

Another LOD Approach

- **Ming & Ward: Multi-resolution Hair Modeling**
    - **http://www.cs.unc.edu/~geom/HSLOD/**
- **Hair is displayed either as a hierarchy of single strand, thinner or thicker structures**
- **Dynamically rearranged according to distance, visibility, and motion**

(a) (b) (c)
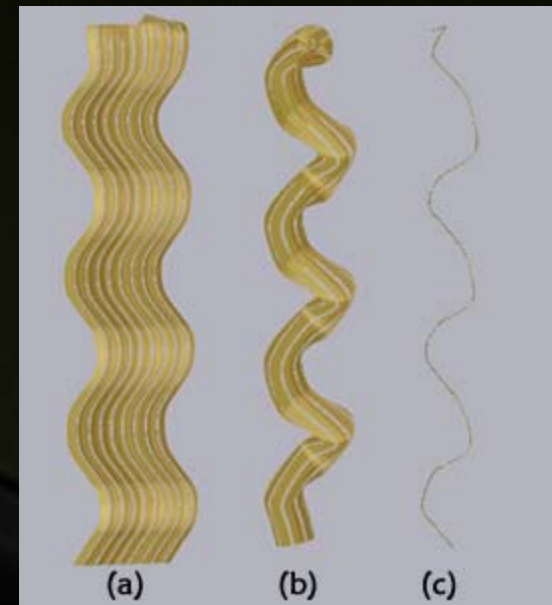
SpyGirl: Enhancing Existing Assets

- From Sami Sorjonen
- http://www.CGMill.com

Character ©2005 Sami Sorjonen

Frame: 0
Perspective

CGMILL.COM

Output from FX Composer
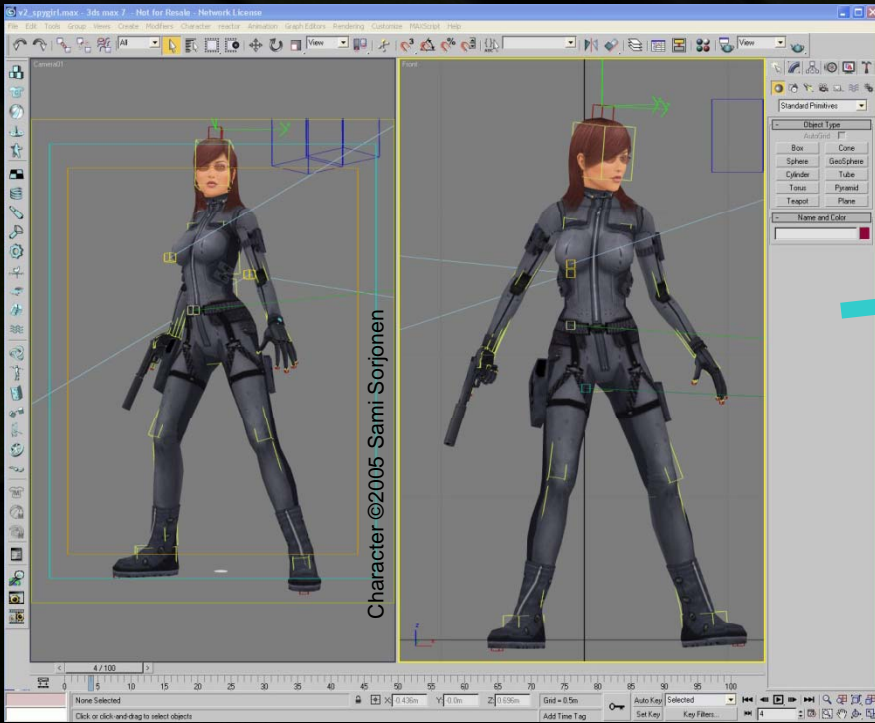
Simple Shaded View in 3DS Max

SpyGirl Shaders - Face

- **Skin: "subsurface scatter" simulation through diffuse rolloff of (N·L)**
  - **Similar to Dawn etc**
- **Eyes: glossy highlight through threshholding**
  - **Wide spec with a cutoff**

Frame: 0
Perspective

Character © 2005 Sami Sorjonen

Red Subsurface Skin Shading & "Wet" Eye Shaders

SpyGirl Shaders - Suit

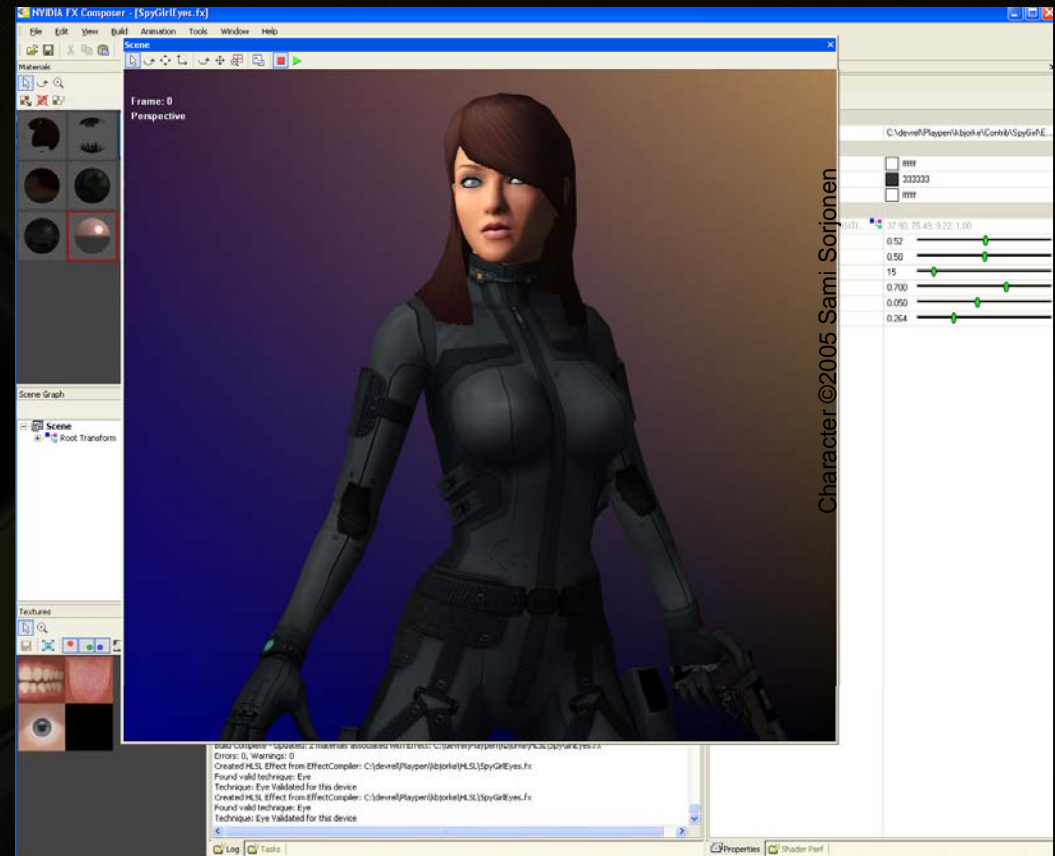- **Adding color changes via "Facing Ratio" gives more solidity to the suit, makes the material seem more complex**

- **Color-change can also be calculated in the vertex shader, essentially for free**

Output from FX Composer

SpyGirl - Hair

NVIDIA.

- **We want to use Kajiya-Kay shading *without hair geometry***
- ***Here's Where We Break a Rule:***
  - **We need an extra asset, since the model didn't already have hair-aligned tangent vectors**
- **For hair directionality, we need a direction map (similar to a normal map)**
- **We can paint one quickly using the library "paint_liquid.fx" shader**
- **FX Composer can save any texture on the fly**
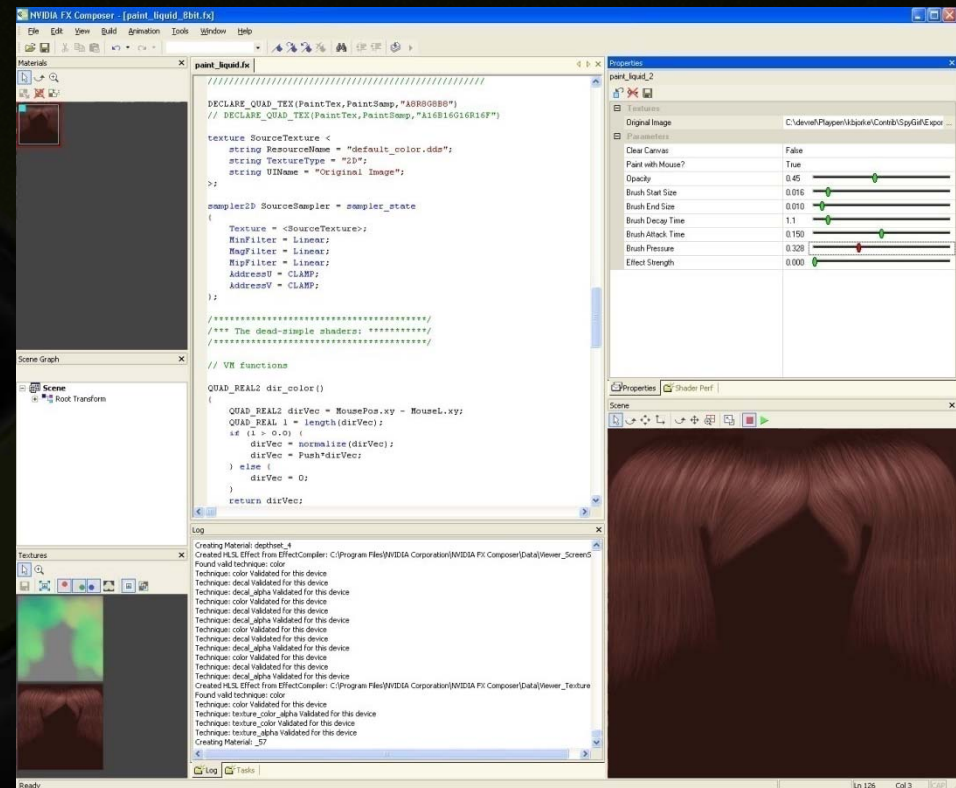
Using "Liquid" to make a hair-direction map

Hair dir map

- **Resize it in Photoshop (doesn't need to be big) and make sure edges are seamless**

Direction Map

Color Map

Applying Kajiya-Kay to Hair Surface

- We use tangent/binormal + direction texture to determine the direction of hair threads

Frame: 0
Perspective

CGMILL.COM

Frame: 0
Perspective

CGMILL.COM

Character ©2005 Sami Sorjonen

Typical Highlight Color

Cyan Highlight for Clarity of Effect

Additional Hair Effects

- **We add a soft (N·L) rolloff, much like the skin (but no extra sub-surface color), to emulate some light scattering in the hair**

- **We add a second rolloff *just for the highlights* for translucent sheen**

Frame: 0
Perspective

Character ©2005 Sami Sorjonen

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Special Thanks: Contributing Artists ⬡ NVIDIA.

These artists and their efforts have provided tremendous inspiration for this talk. See more of their works!

Krishnamurti Costa
- http://www.antropus.com/

Sami Sorjonen
- http://www.cgmill.com/

Toko Voom
- http://www.flickr.com/photos/8336685@N04/

Ina Centaur
- http://www.inacentaur.com/

Larissa Starostin
- http://www.flickr.com/photos/larissastarostin/

Luna Zolnir
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Phedre Dumouriez
- http://www.flickr.com/photos/fedry/

Louise Numan / Dantalion Halberd
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Ia.Chandra
- http://www.flickr.com/photos/lachandra/

Joshua Morane
- http://www.flickr.com/photos/last_exit/

Nedeko Kohime (Anja Cerwonski)
- http://www.flickr.com/photos/nedeko/

Dee Dee Deepdene
- http://www.flickr.com/photos/deedee_deepdene/

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·ĊЯФШ·
- http://www.mydarkesthour.net/

ColeMarie Soleil
- http://www.flickr.com/photos/rockerfaerie/

Connie Sec
- http://www.flickr.com/photos/conniesec/

Darks Adria
- http://www.flickr.com/photos/22383183@N06/

Gita Rau
- http://www.flickr.com/photos/gitarau/
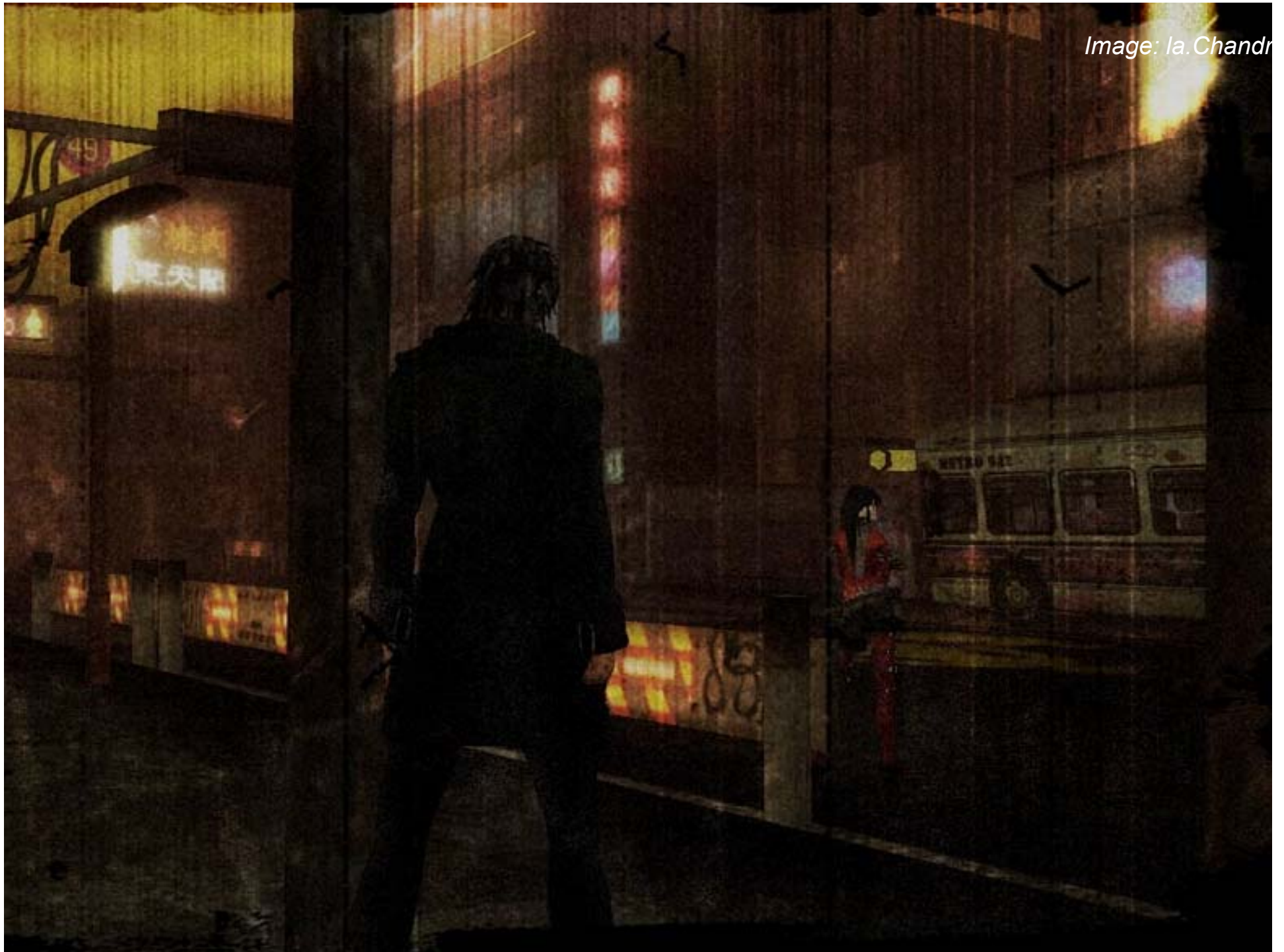
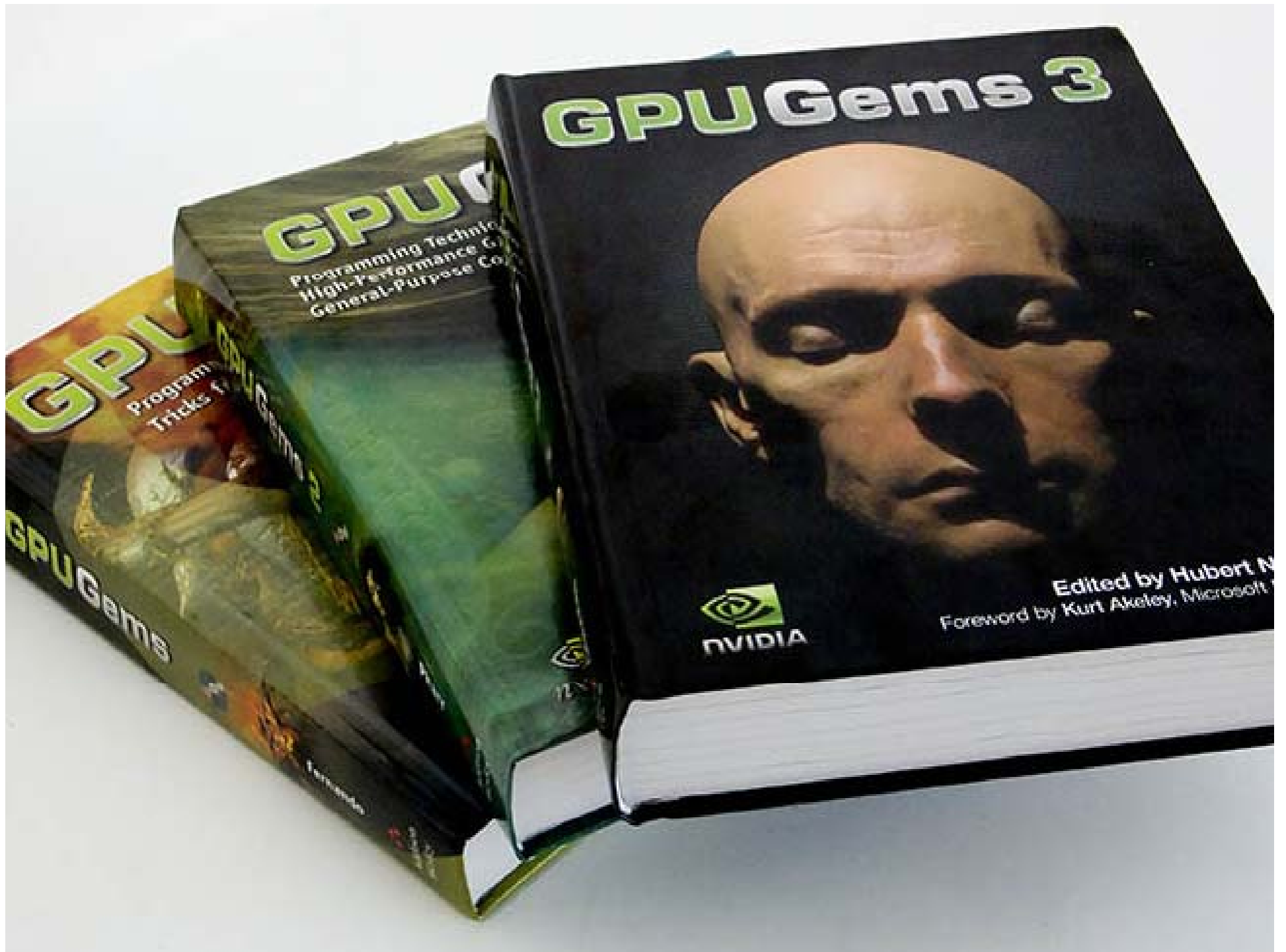"If you deliberately set out to be less than you are capable, you'll be unhappy for the rest of your life."

Abraham Maslow

Q & A

Image: Sixtine Ka

GPU Gems 3

GPU Gems

Programming
Tricks

GPU Gems 2

Programming Techniques
High-Performance G
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Edited by Hubert N

Foreword by Kurt Akeley, Microsoft

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http://developer.nvidia.com/

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