



**nVISION 08**  
THE WORLD OF VISUAL COMPUTING

# Beautiful Women of the Future

Kevin Bjorke, NVIDIA



# Beautiful Women of the Future

Image: Luna Zolnir



*Image: Mia Olivier*





*Image: Darks Adria*



*Image: Lunarose Graves*

# Agenda

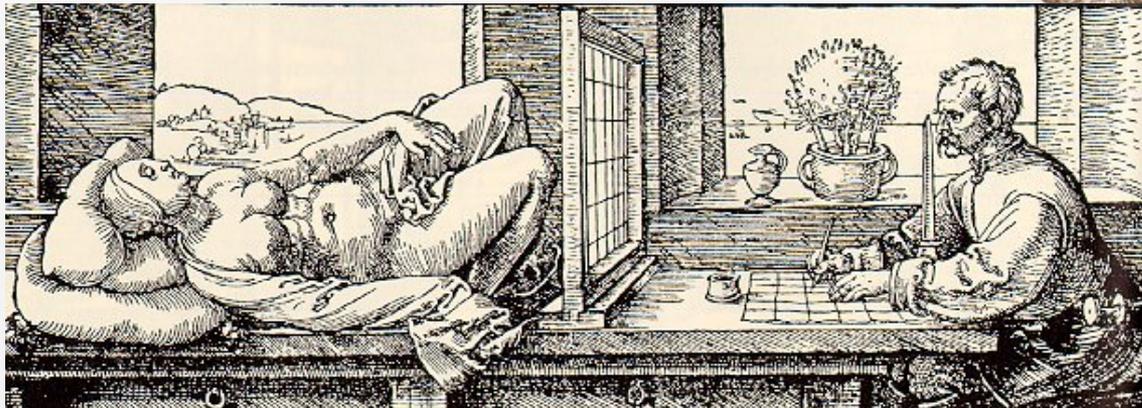
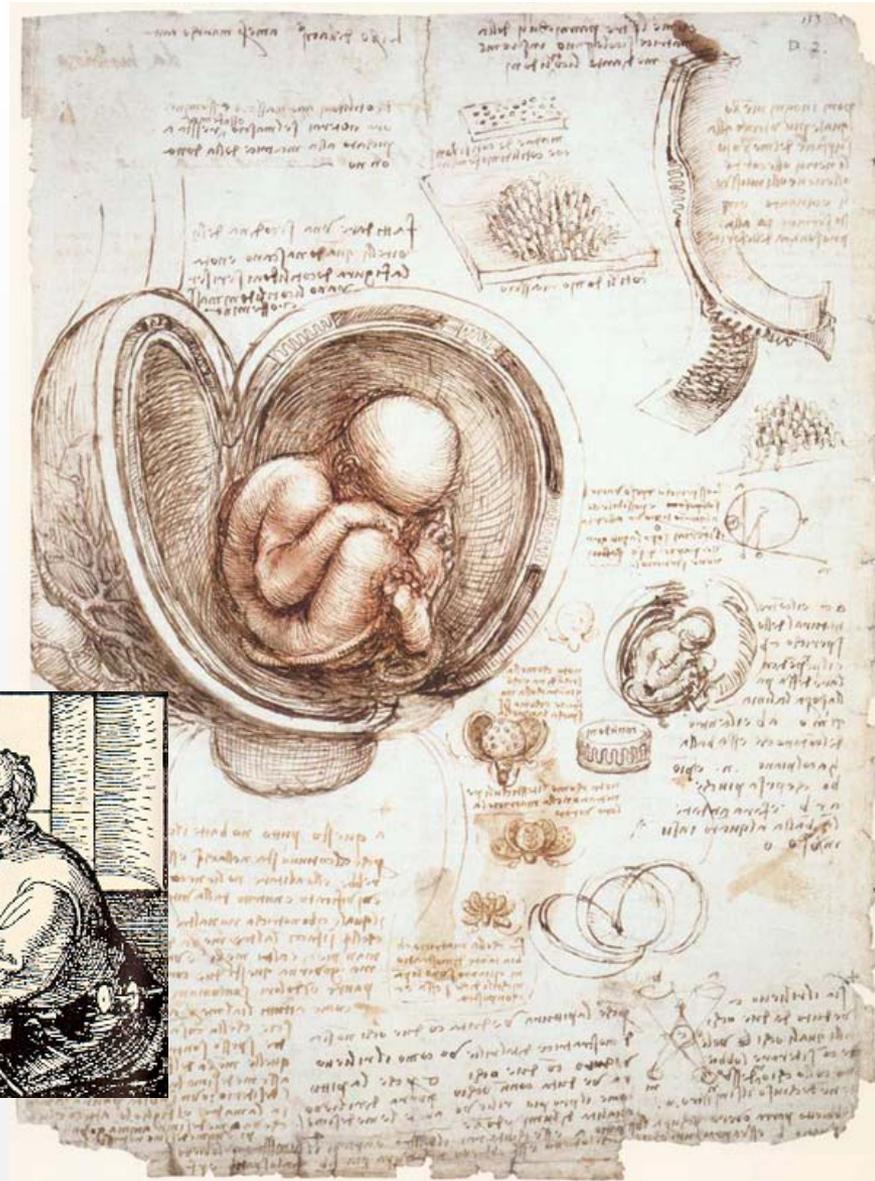
- **Background**
- **Characters**
  - Their roles in gaming
- **Techniques**
  - Behavior
  - Clothing
  - Skin
  - Eyes
  - Hair



# Technical Artists



...have always  
been around!

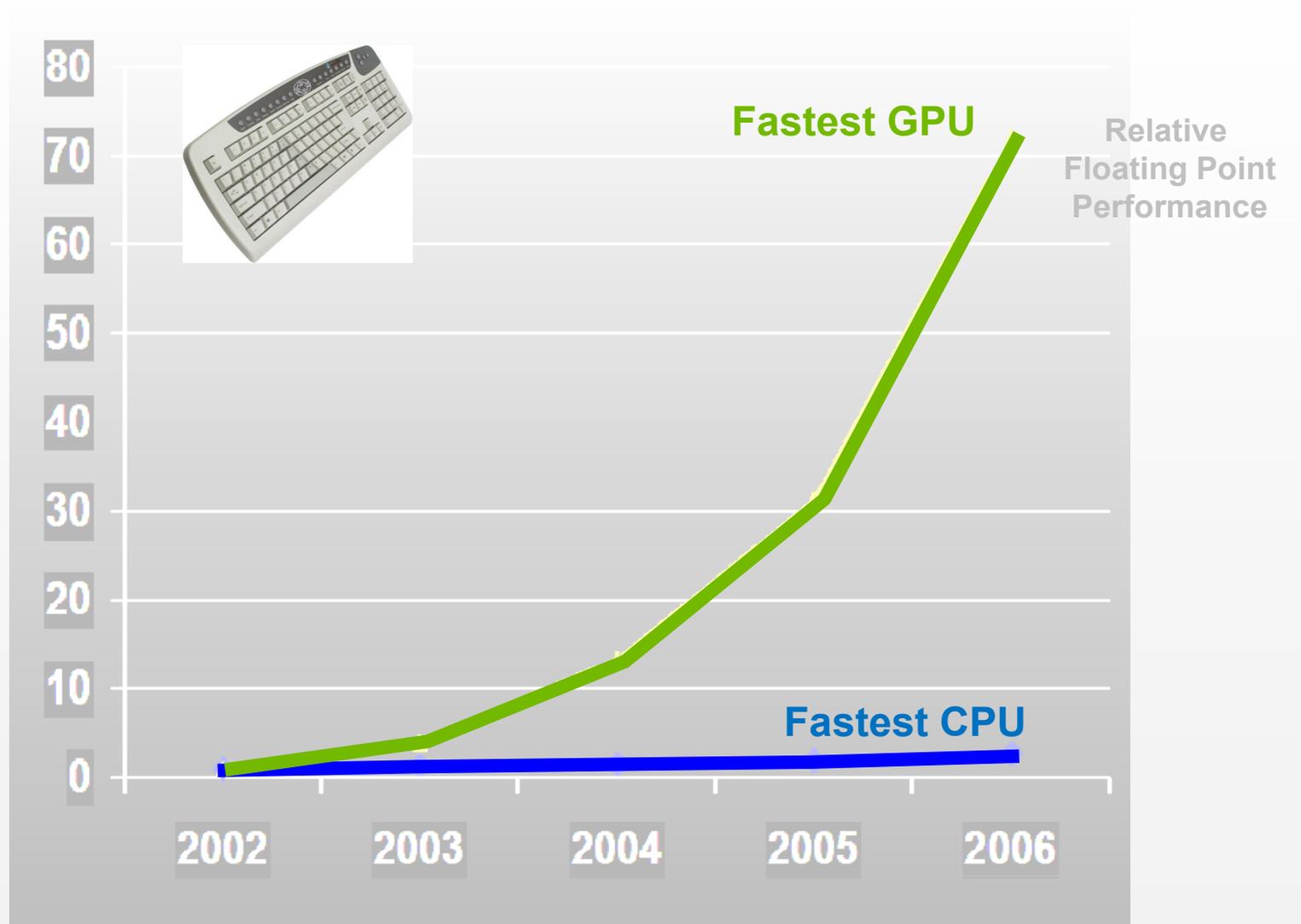


A woman in a shimmering, metallic, form-fitting outfit is floating in a field of red flowers. She has her arms outstretched and is looking upwards. Behind her is a large, colorful parrot with blue, yellow, and white feathers. The scene is set against a clear blue sky. The overall mood is joyful and celebratory.

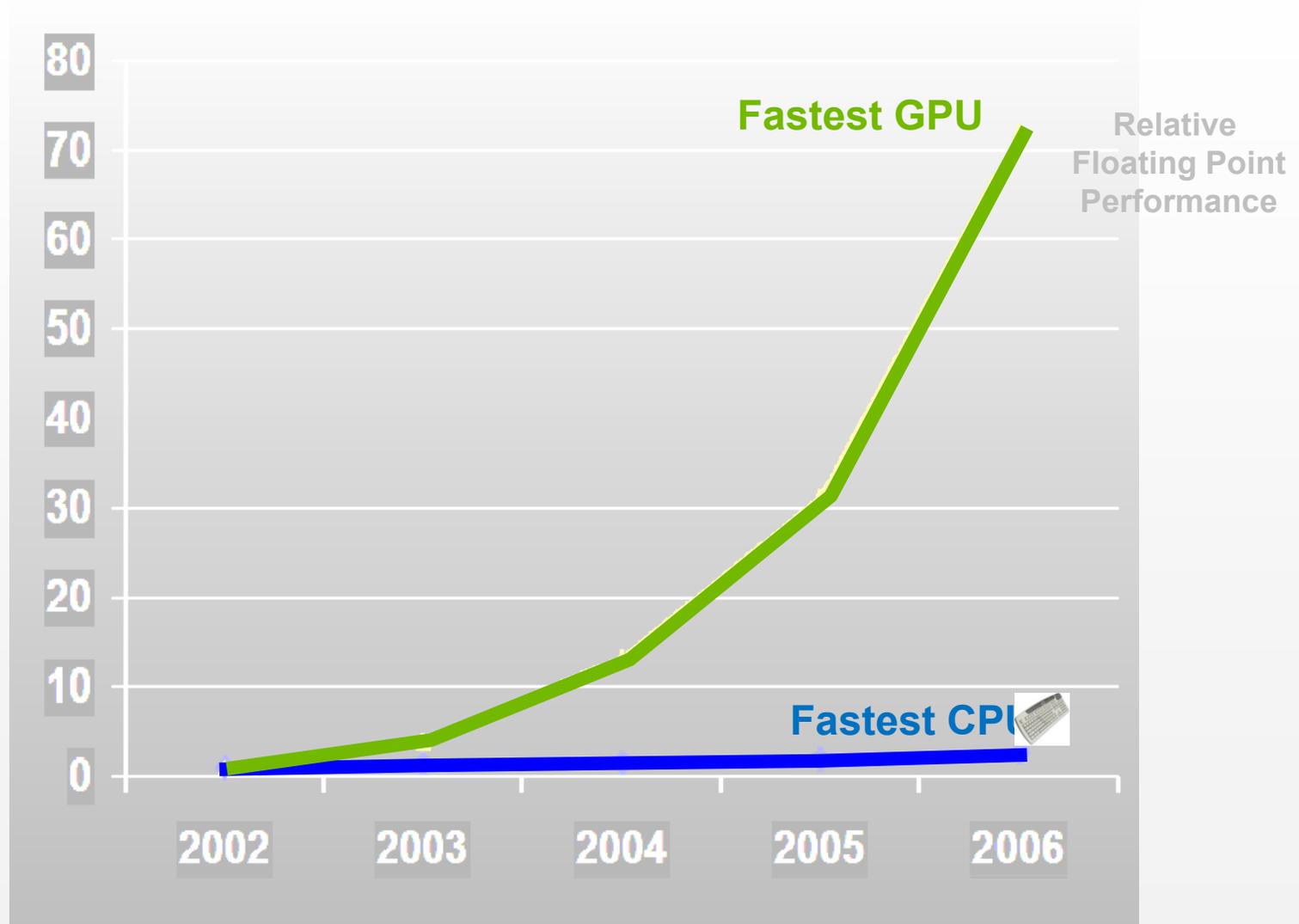
# The Happiness Business

*Image: Axelia Meili*

# Moore's Law to the <sup>N</sup>



# Moore's Law to the <sup>N</sup>



世界最大

VIERA



103v型フルハイビジョンプラズマ

50v

50v



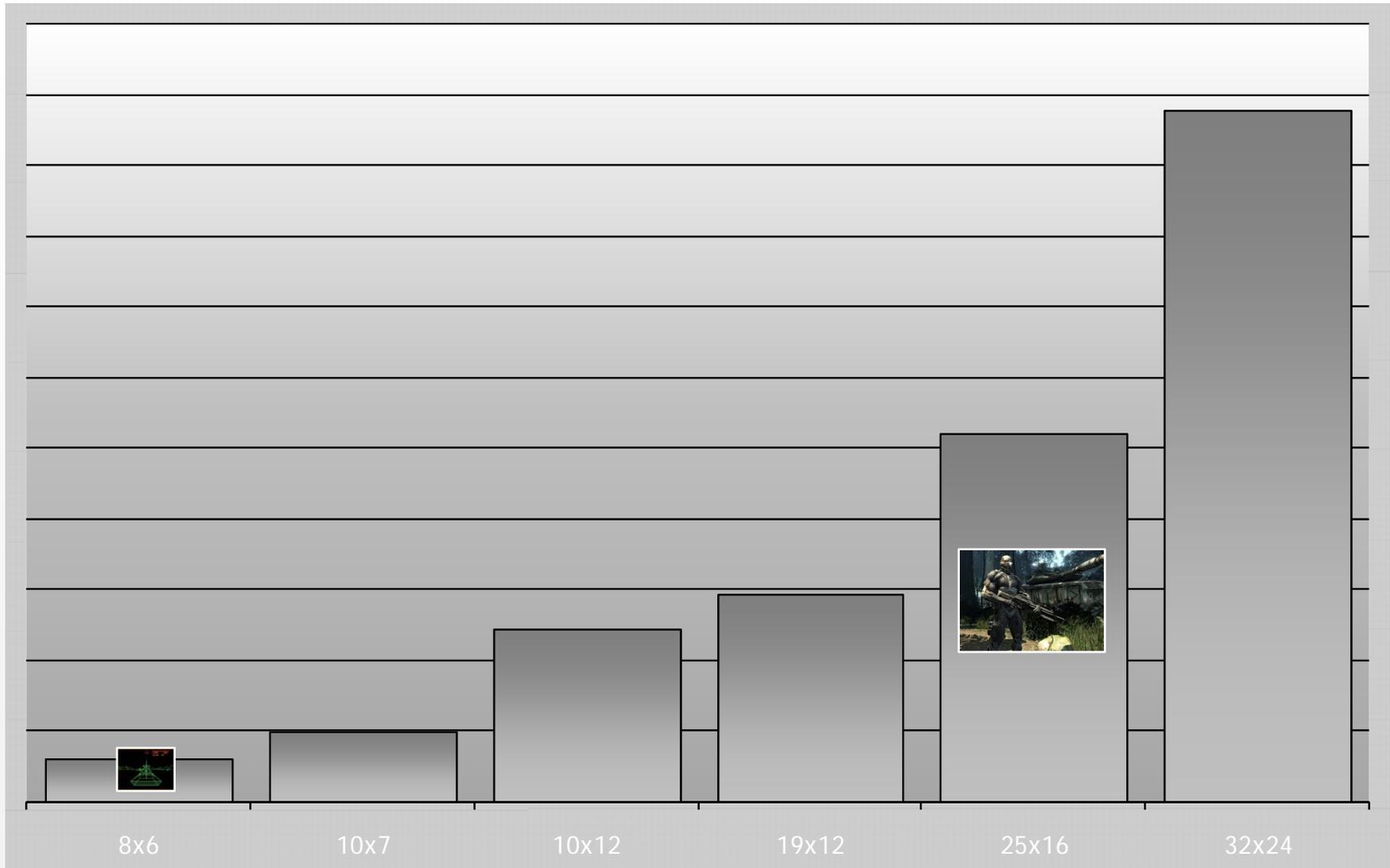
Nice TV

NEW

世界最大

103v

# Changing Formats







# Stampeding Content



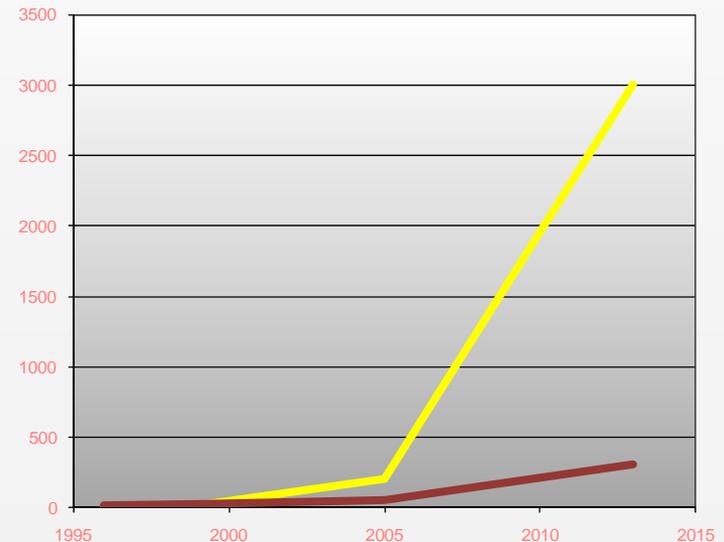
## From Evan Hirsch at Gamefest:

- 1996: 4MB Artwork, 8-12 人
- 1999: 10-15MB Artwork, 15-20 人
- 2005: 200+ MB Artwork, 25-??? 人

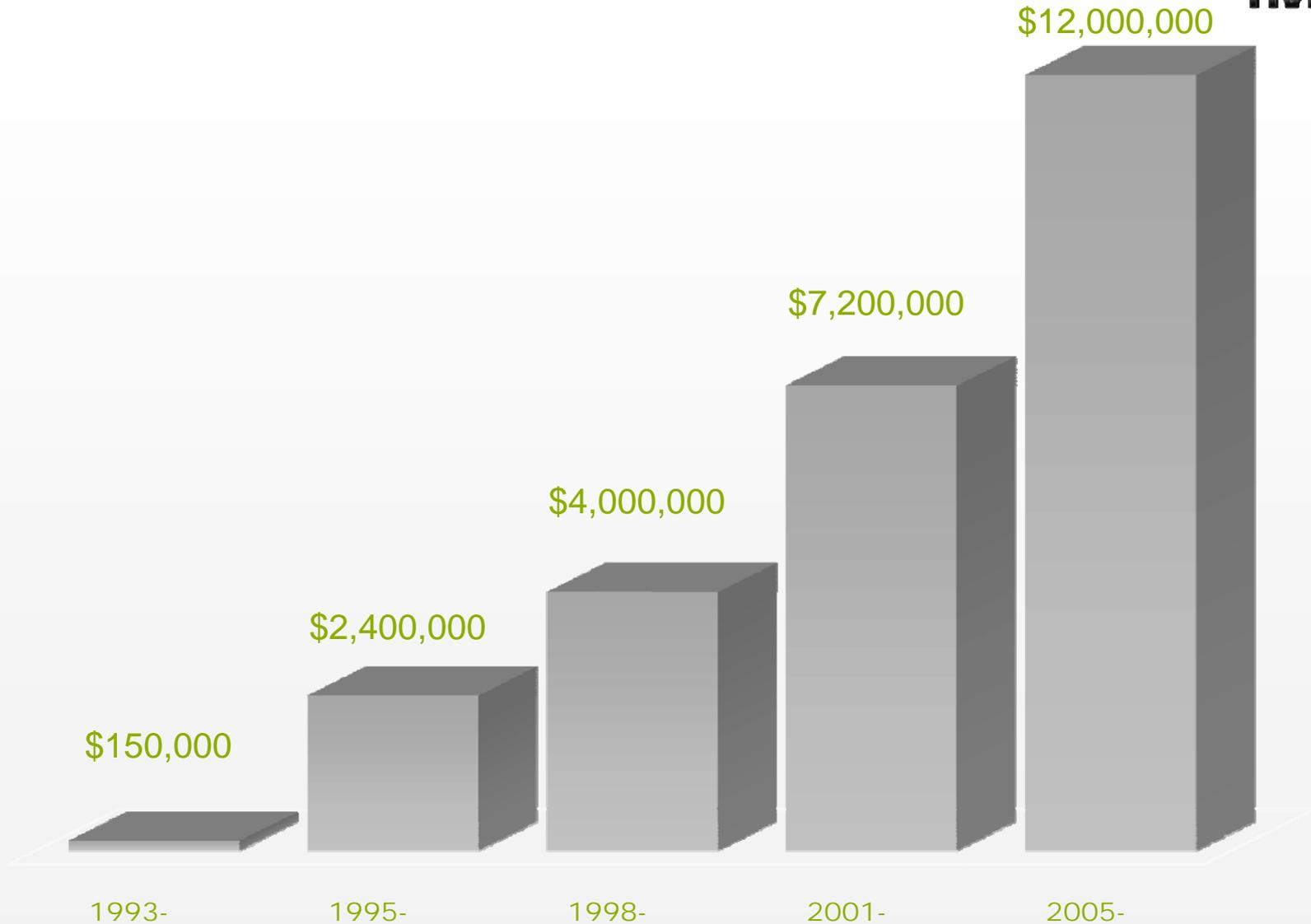
## Where would this trend lead?

- 2013: 3-5GB Artwork, 300+ 人?

## Can *anyone* afford this?



# Rising Triple-A Game Budgets



# Reining-In Content Budgets



## ● Technology: Friend and Foe

### ● Foe:

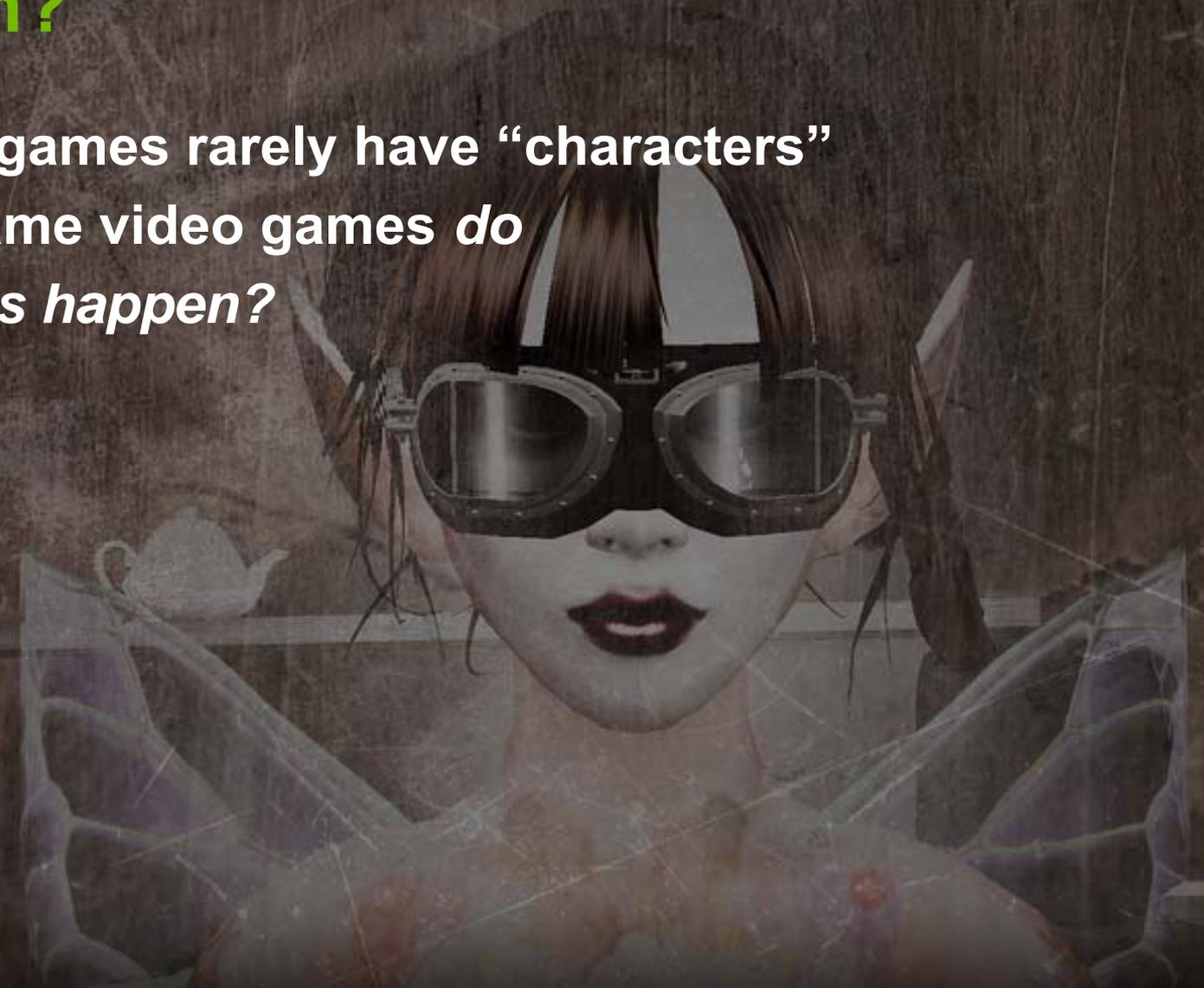
- Added sophistication raises the danger of ever-more-burdensome noodling

### ● 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?*



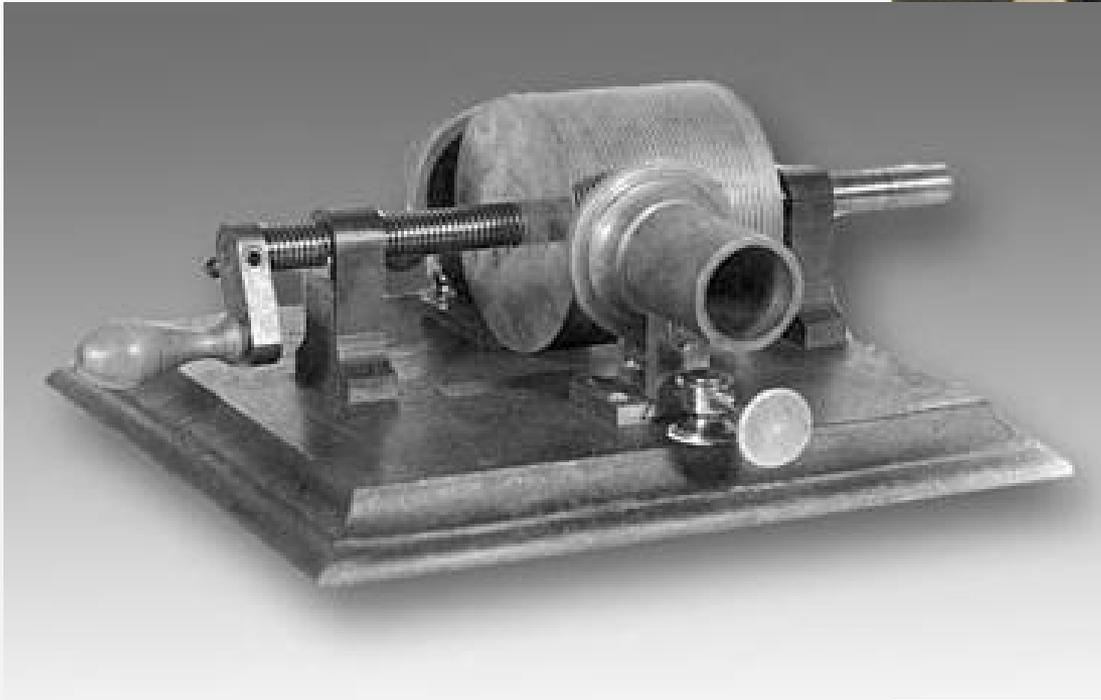
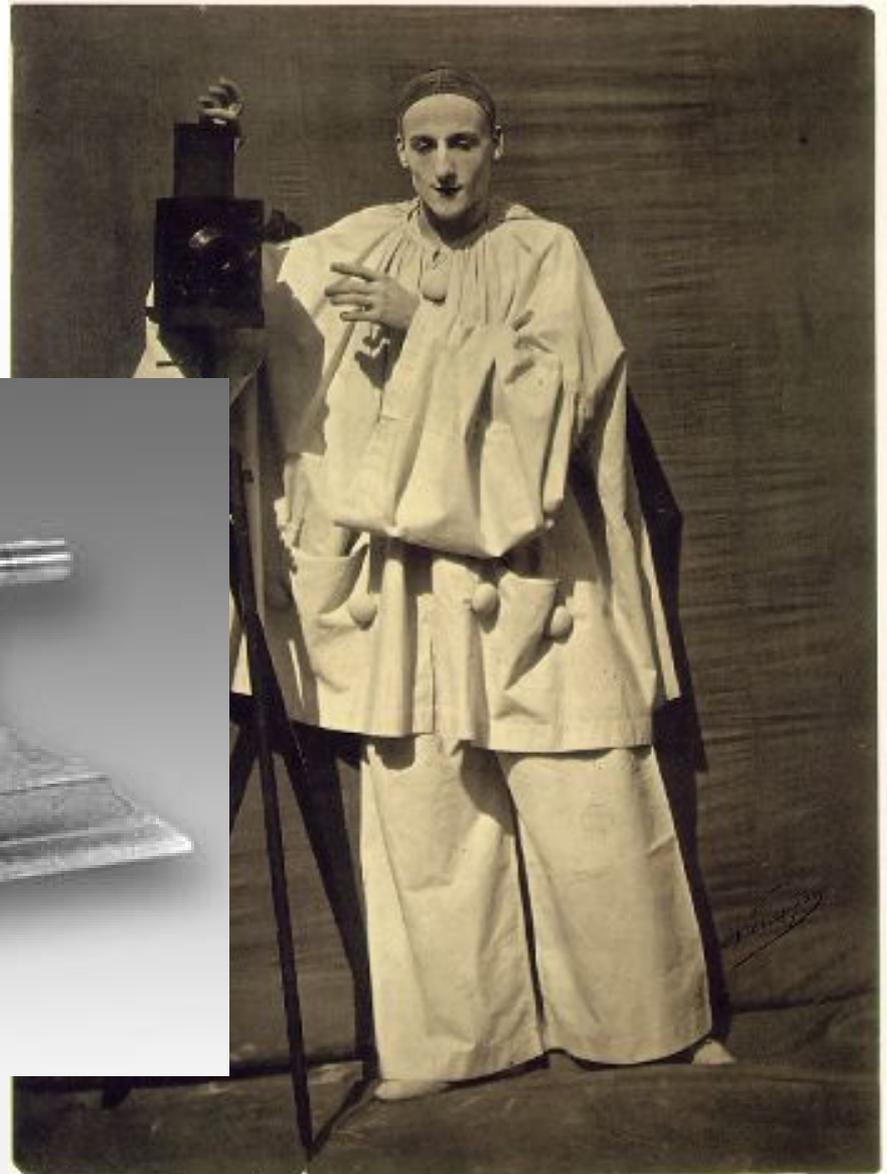
# Two Branches of Art



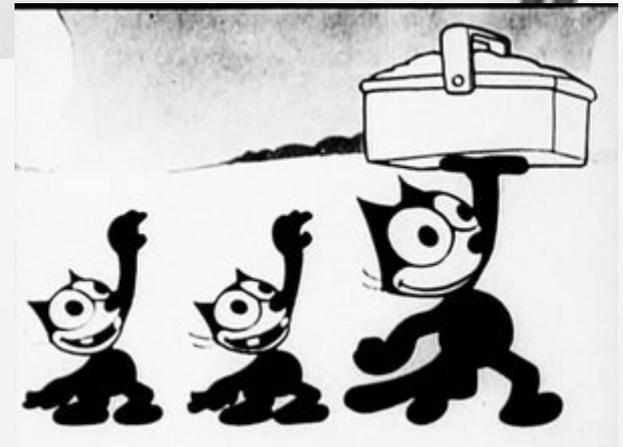
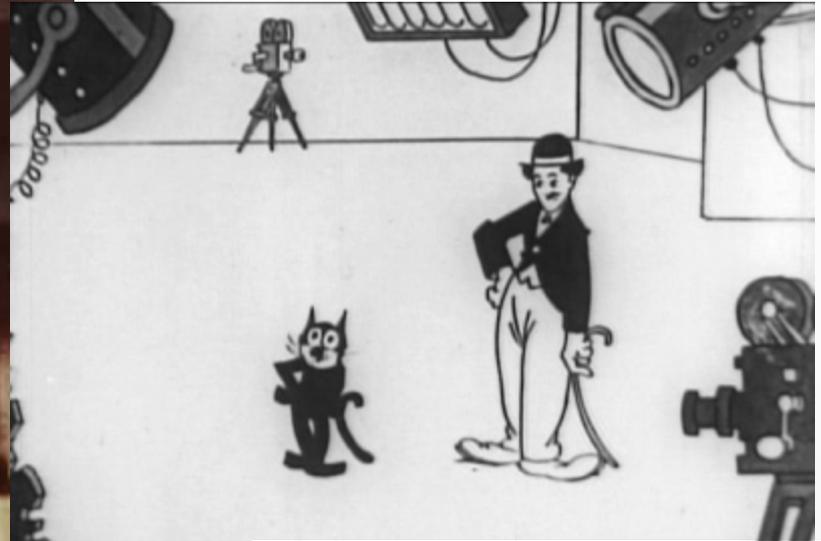
# Two Branches of Art

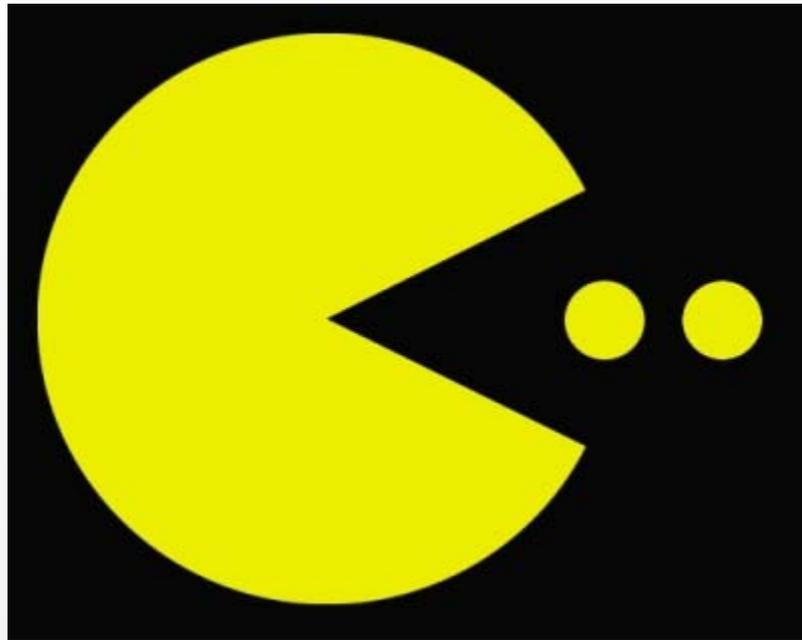


# The Industrial Revolution

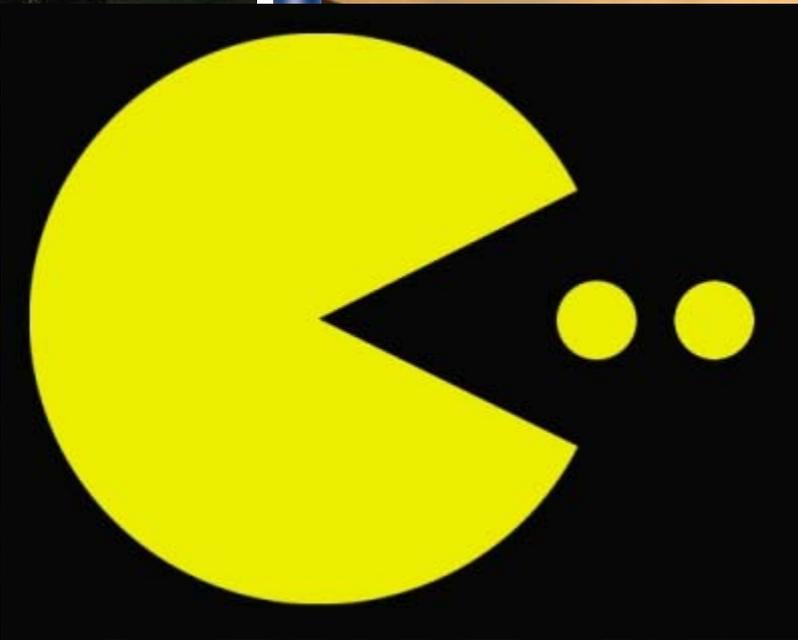


# Watch Me Now!

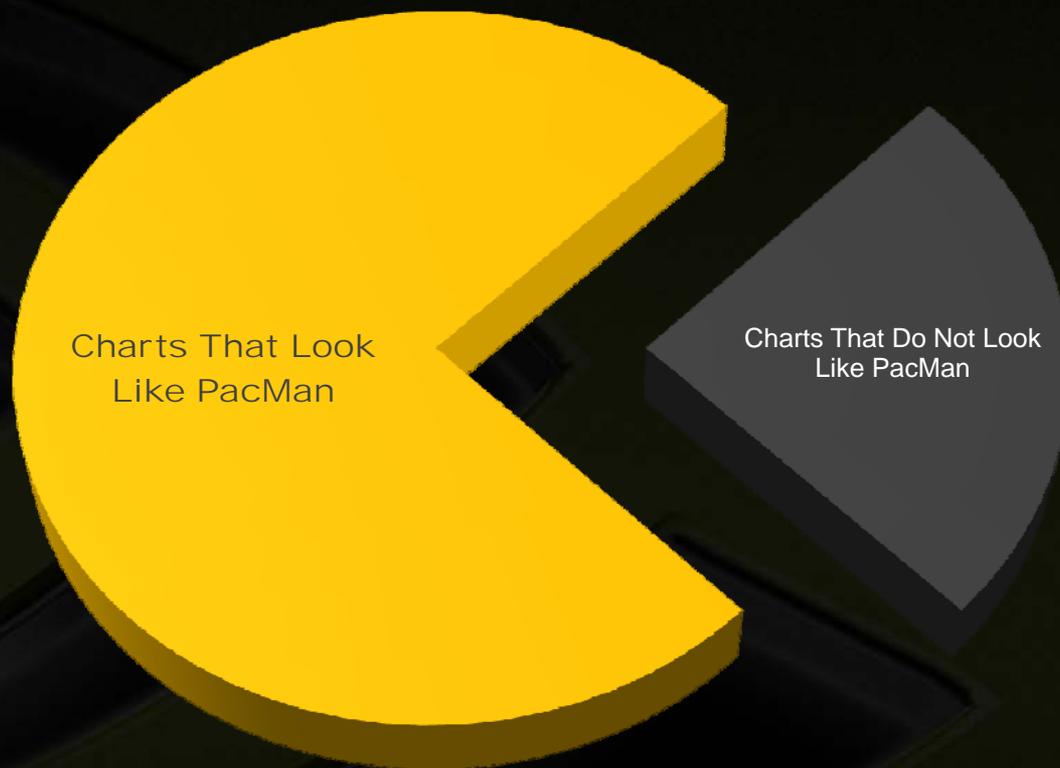








# Games Are Mainstream Culture





**wherez my master sord**

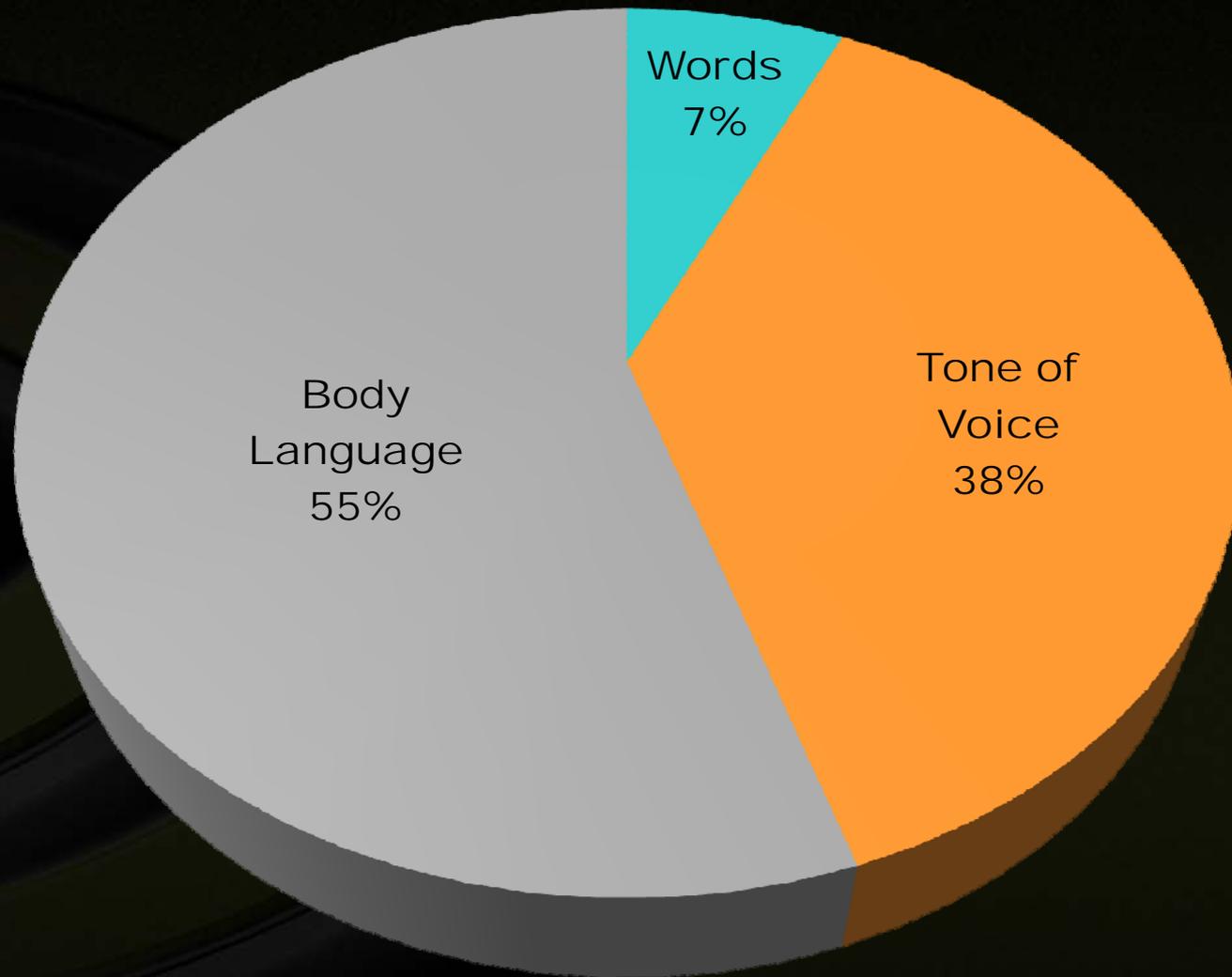




# The Importance Of Beauty



# Mehrabian's Rule: 7-38-55





*Image: Dee Dee Deepdene*

Image: Nedeko Kohime



# Characters with Character



# 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/>



©2008 Krishnamurti Costa

# Which Genres Benefit Most?



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



# Changing Expectations



Baked Lighting

Vertex Lighting

Per-Pixel Lighting



# 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?

A woman with dark hair is sitting on a black wooden chair, viewed from behind. She is wearing a dark, sleeveless top and light-colored pants. Her hands are raised to her face, and she appears to be looking out a window. The room is dimly lit, with a strong light source from the window creating a bright glow and casting shadows. The walls are made of brick. The overall mood is contemplative and artistic.

Focus on the Experience,  
Rather than the Technology

*Image: Kean Kelly*

# The Sofa, or the Desk?



# The XeoDesign Chart



Source: <http://www.xeodesign.com/>

# The XeoDesign Chart



FPS

Puzzle



Social

RTS

Source: <http://www.xeodesign.com/>

Context Can Override "Content"



# Context Can Override "Content"



# The Avatar Business: More than Just 3D Characters







# User-Generated Content Is User-*Specific* Content







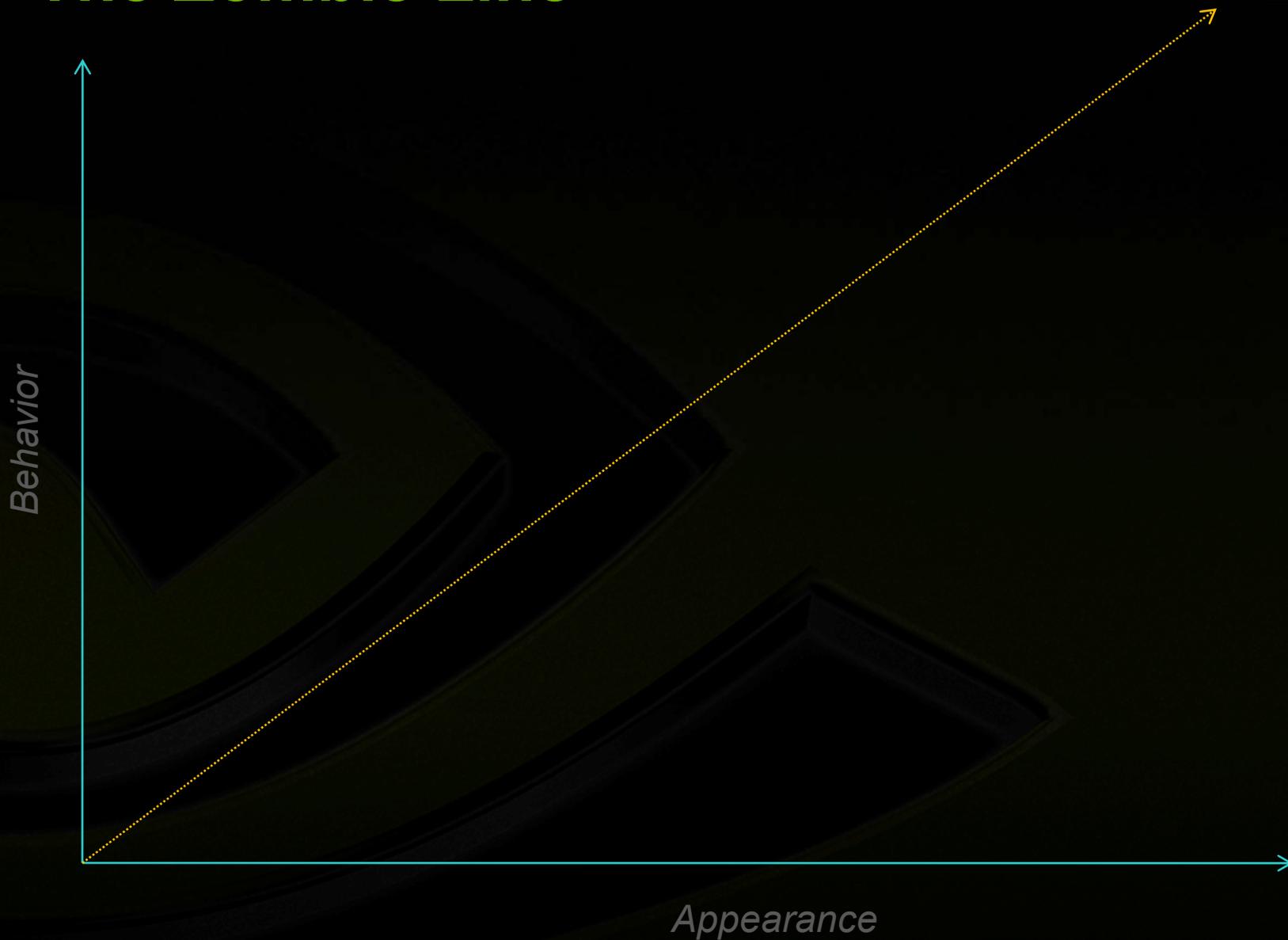


POWERED BY

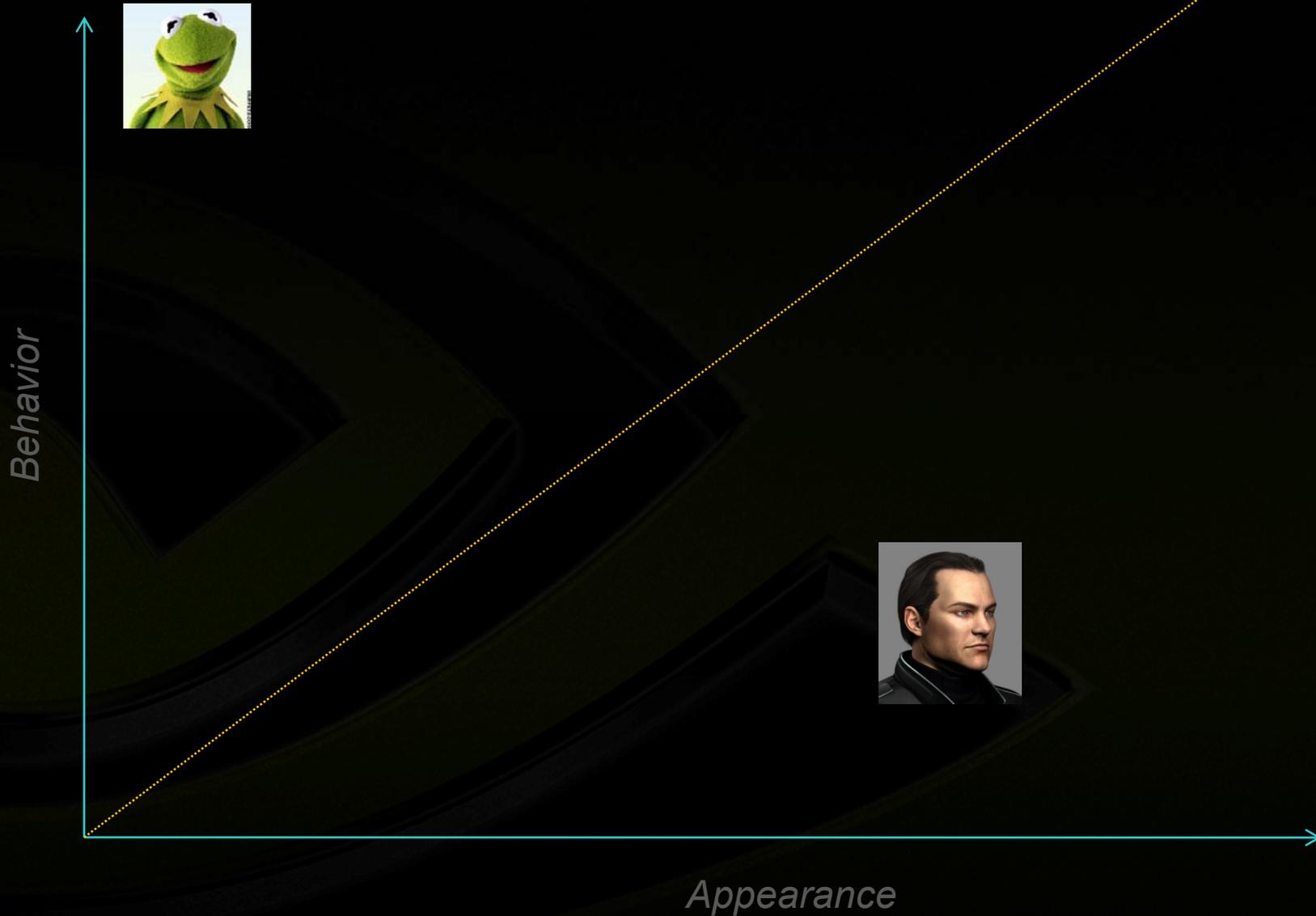


UNREAL  
TECHNOLOGY

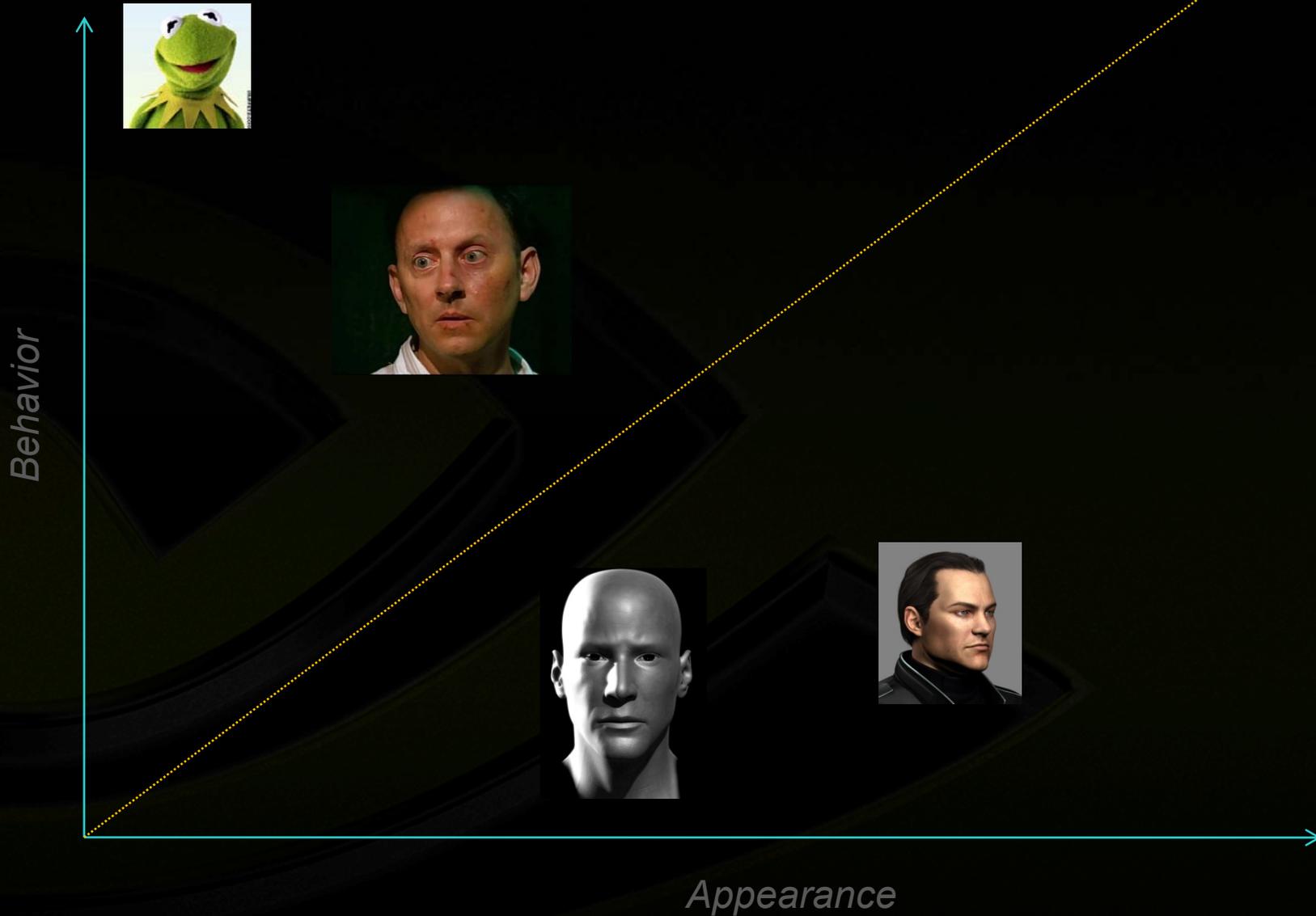
# The Zombie Line



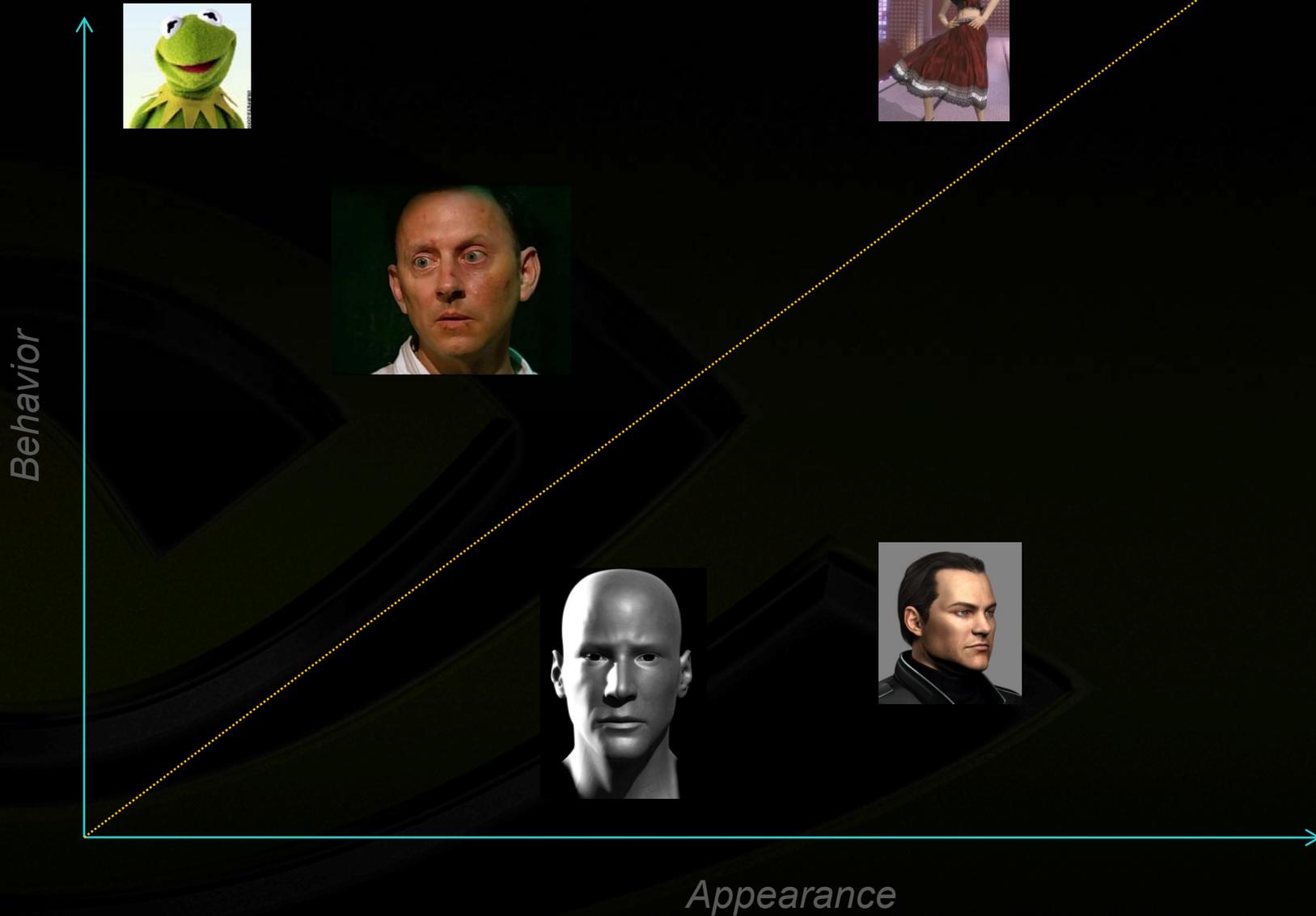
# The Zombie Line



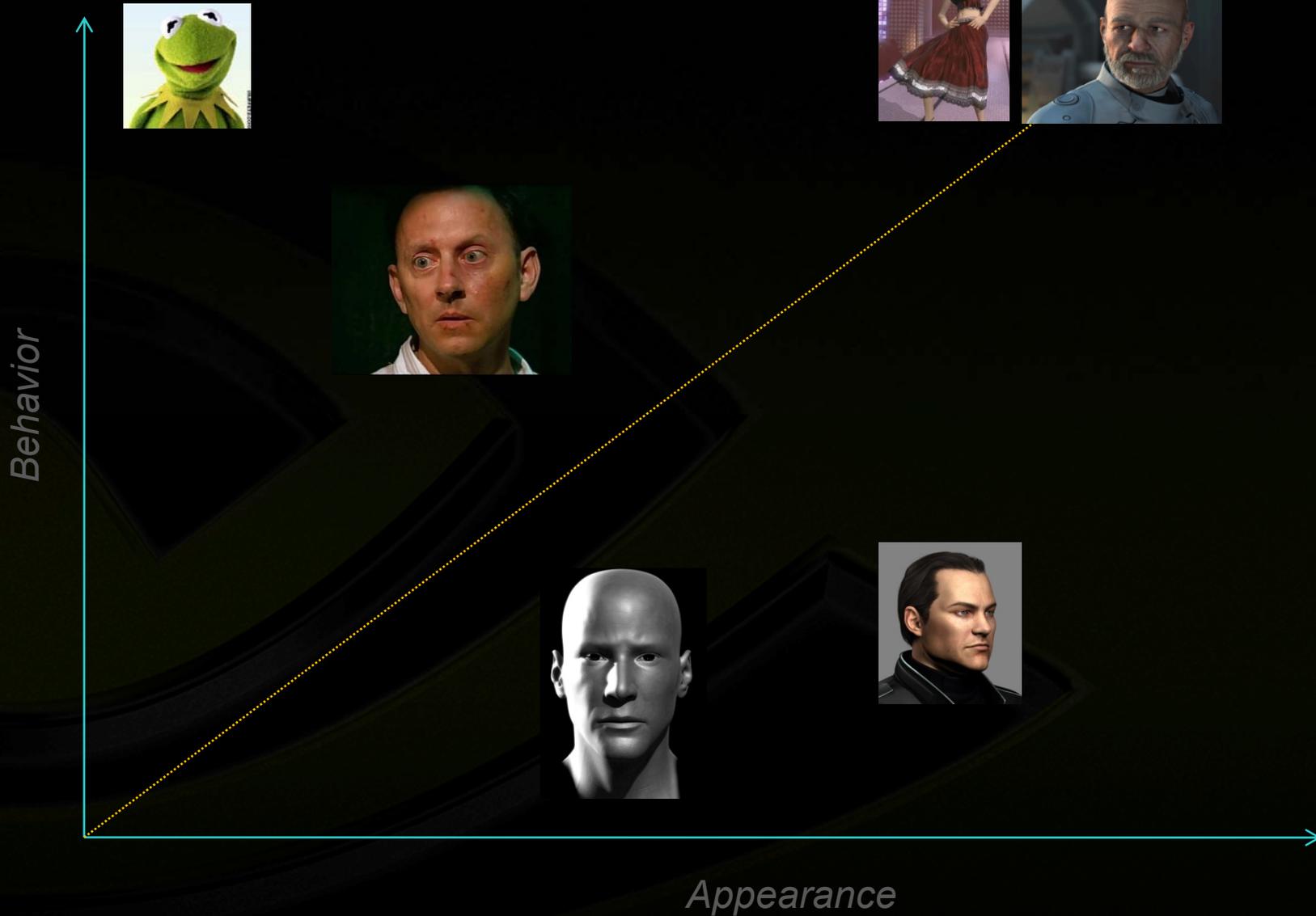
# The Zombie Line



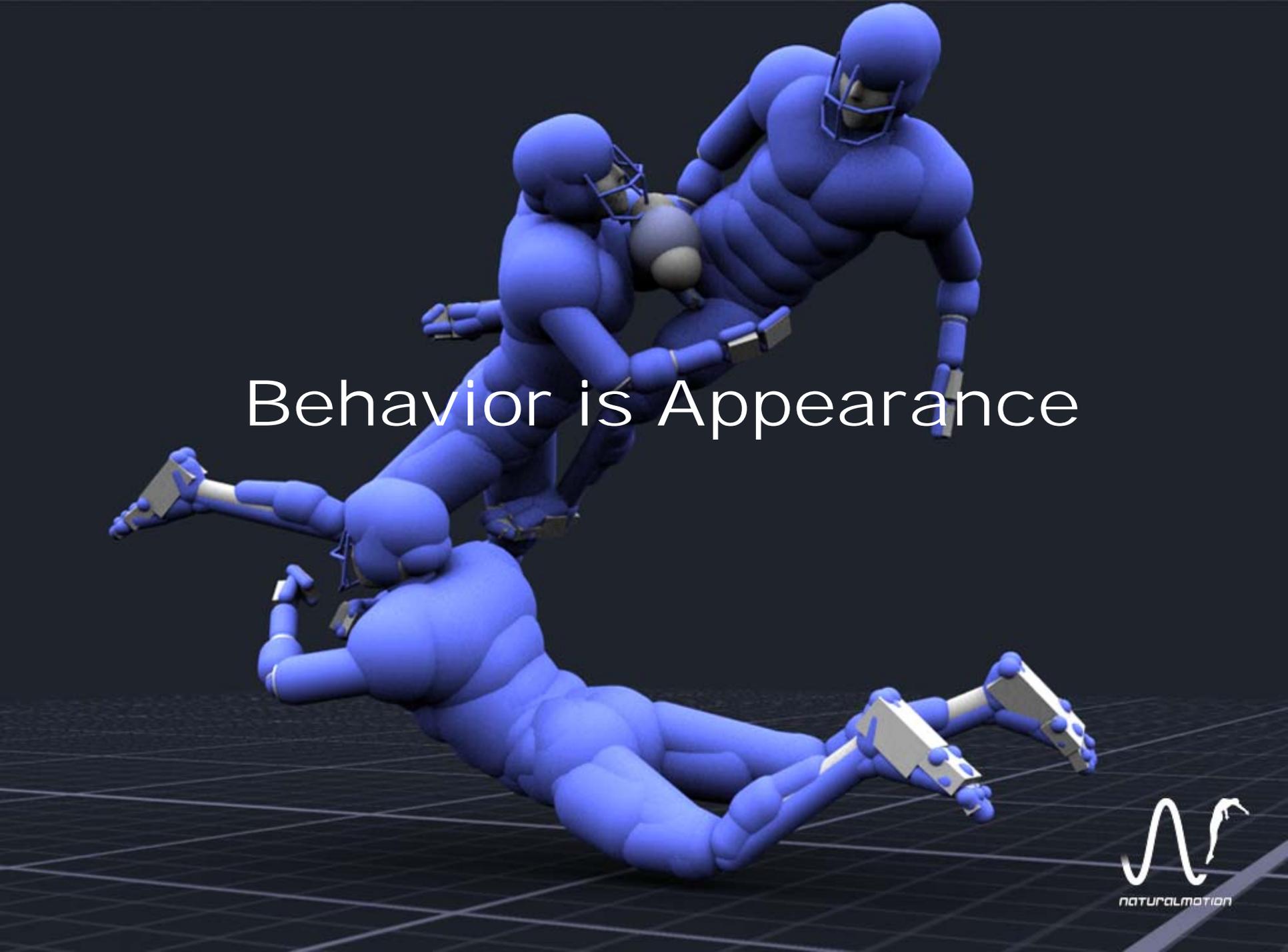
# The Zombie Line



# The Zombie Line





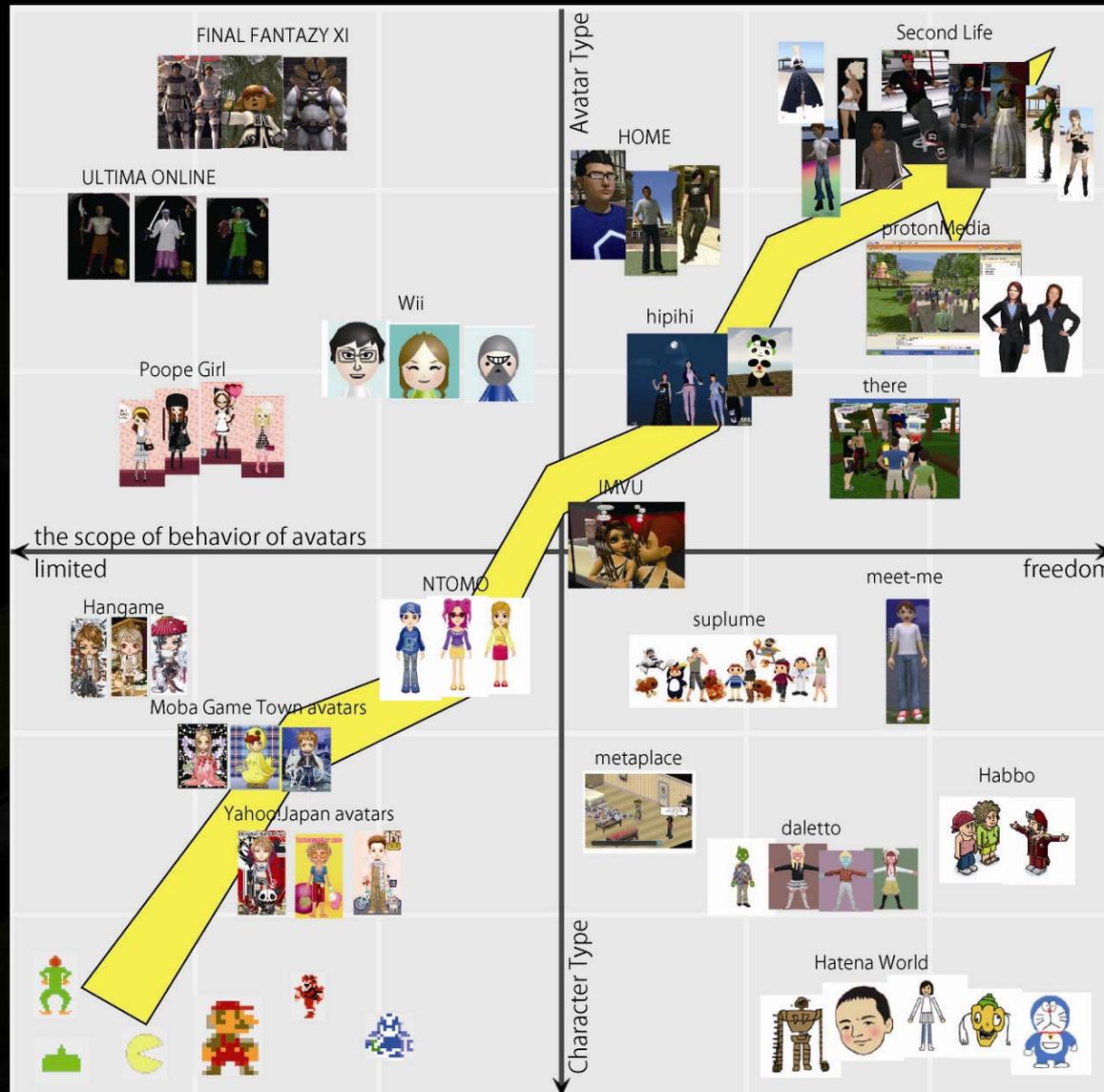
The image features three blue, muscular humanoid figures in a dynamic, action-oriented pose on a dark grid floor. One figure is lying on its back, another is leaning over it, and a third is positioned above them, all appearing to be in a state of intense physical activity or combat. The figures have a highly detailed, anatomical appearance with visible muscle groups. The text "Behavior is Appearance" is overlaid in the center in a white, sans-serif font.

Behavior is Appearance

# A Brief Video Interlude...



# Appearance & Freedom



# Overlap, Squash & Stretch

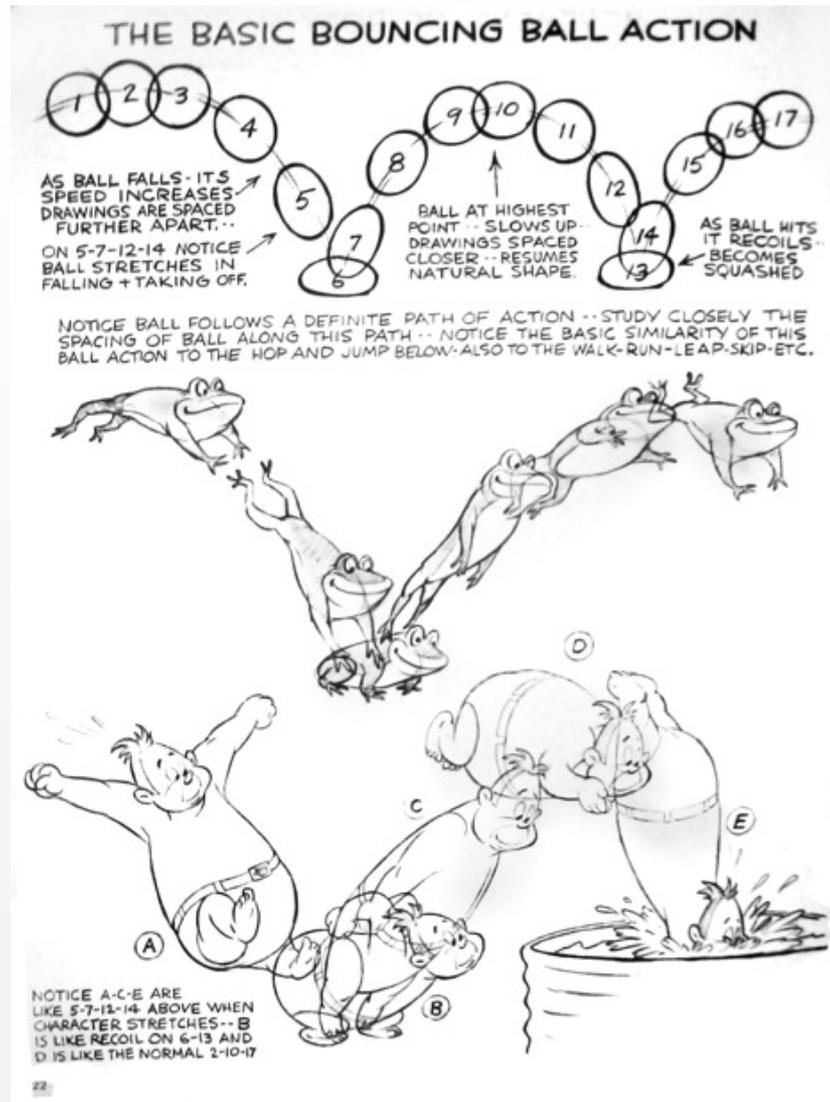


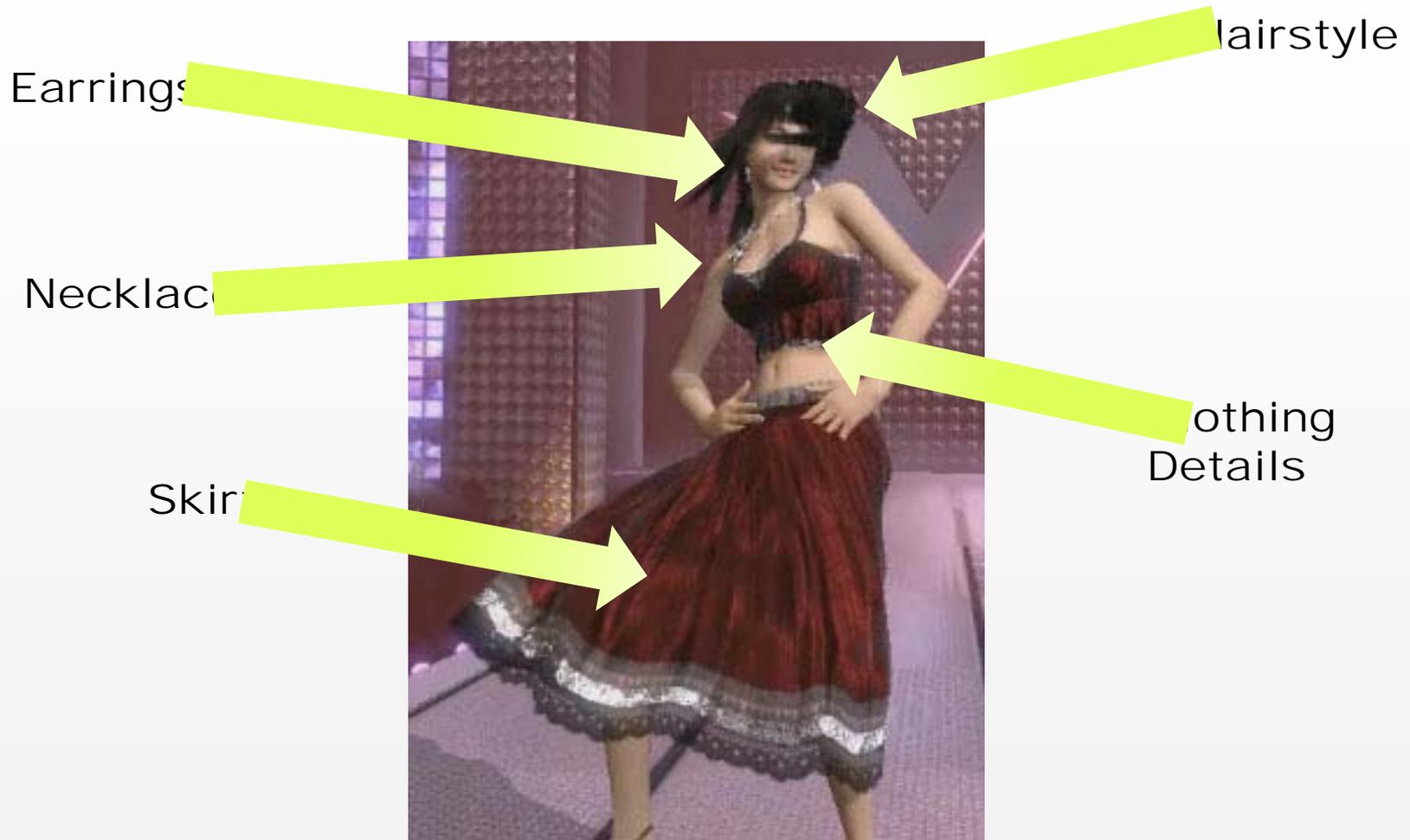
Image: Dee Dee Deepdene



# Nurien, Clothing, Follow-through



# Endless Overlap



# Just for Dancers?



# Just for Dancers?





# Different Approaches for Different Consumers

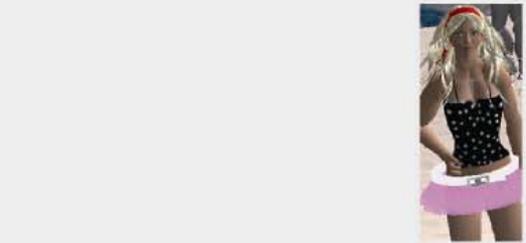
# Different Regions, Different Toons



- 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





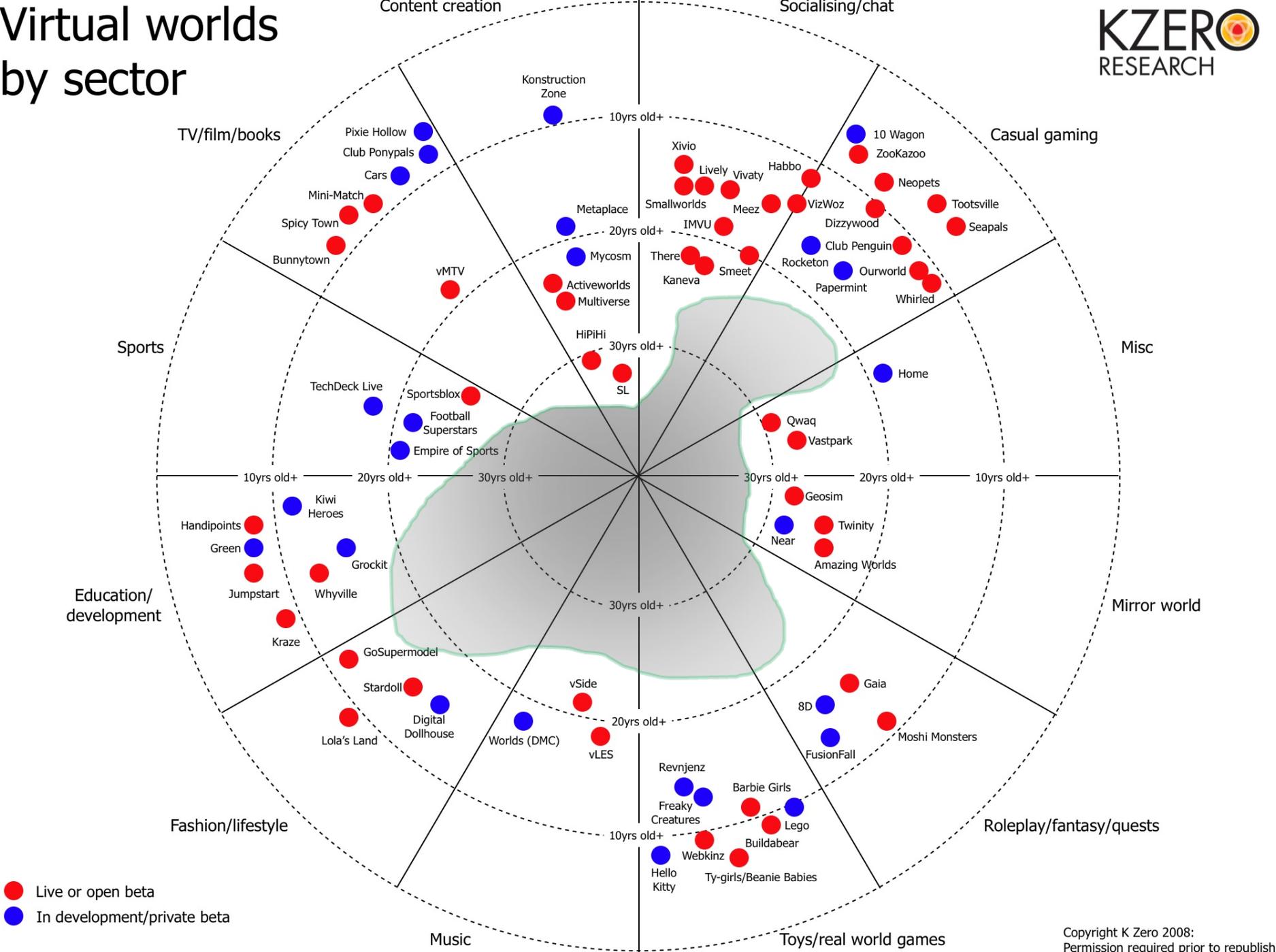


Images: F. Paine & Gita Rau

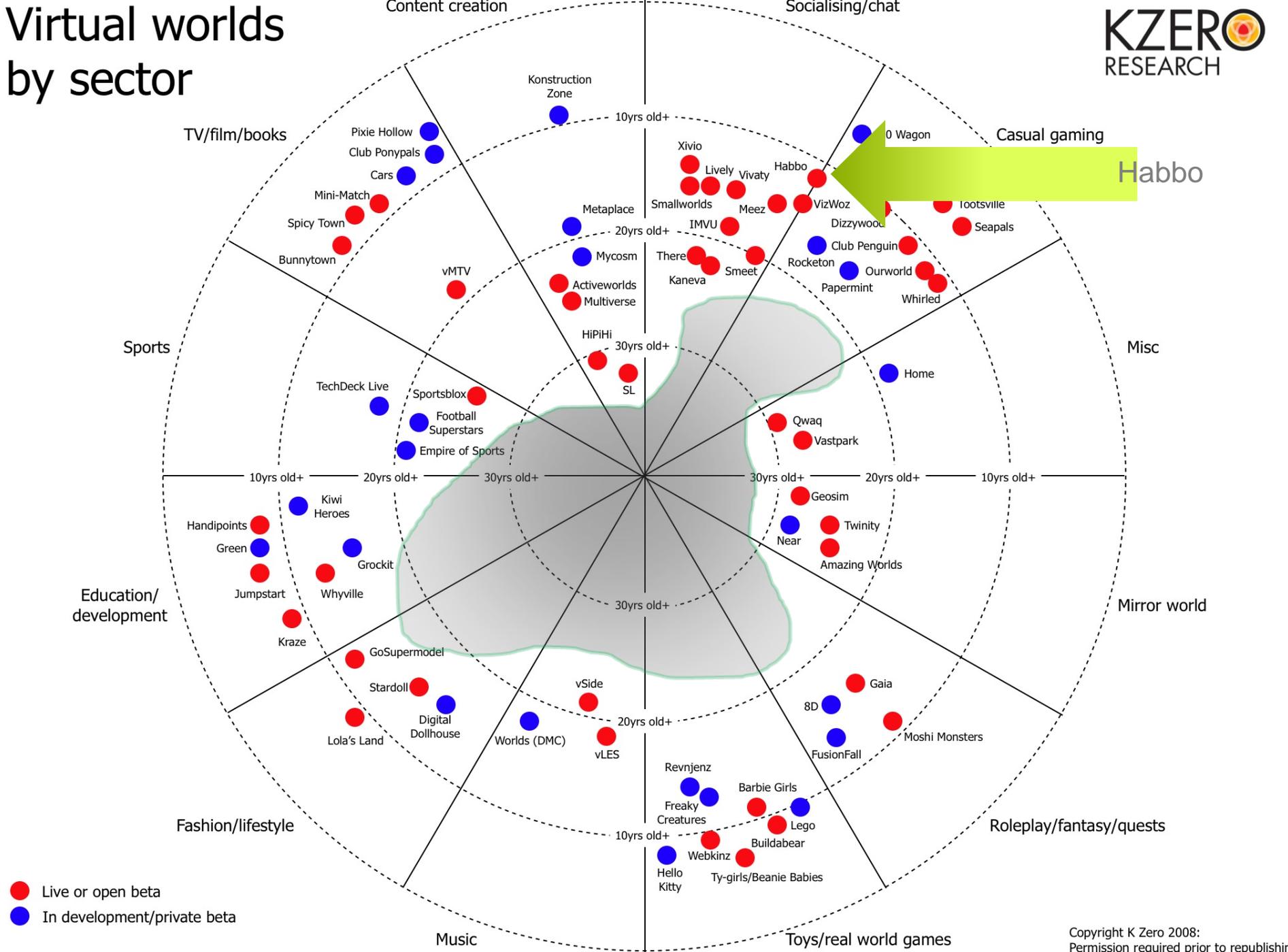




# Virtual worlds by sector



# Virtual worlds by sector







All Virtual Worlds  
Are driven by fashion





*Image: Nedeko Kohime*





Image: Dantalion



*Image: Prinz Photostudio*



*Image: Larissa Starostin*



Follow me.

Where is every

Lets go to your Ho

scee-paulr

scee-swaugaman

scee-mgoodwin

scee-fluffBaronG

ThreeRadio

Clarence Patel

Jimbo

Robert

Samantha Flou

amanceytest1

scee-jlm



home



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



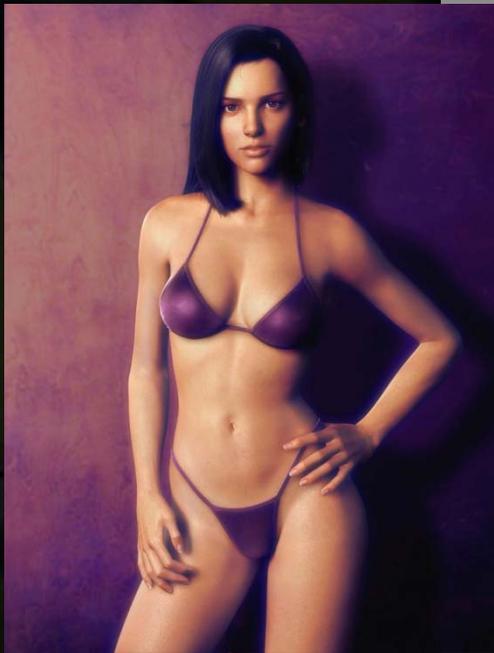
- Without shading, it's just so many polygons



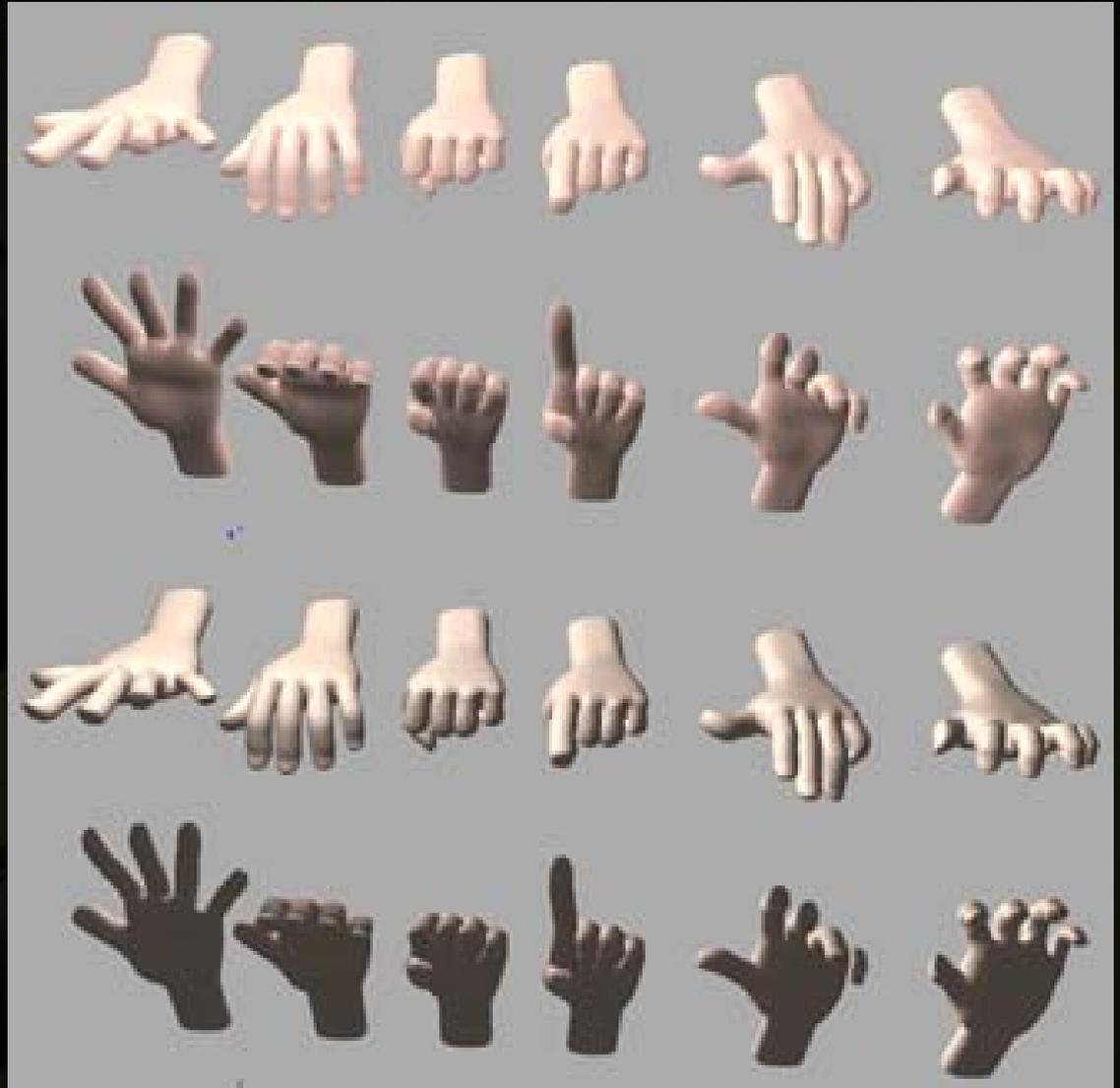
# Skin



- Without shading, it's just so many polygons



- Even in “cartoony” contexts, skin can have a special character



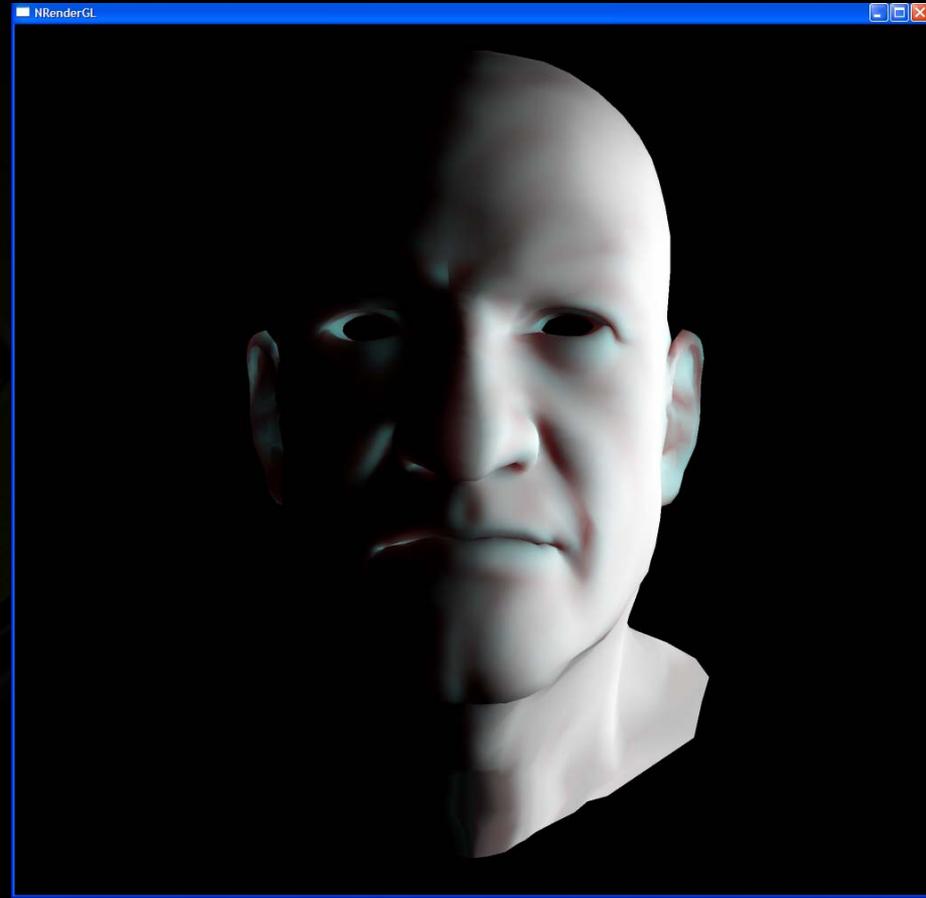
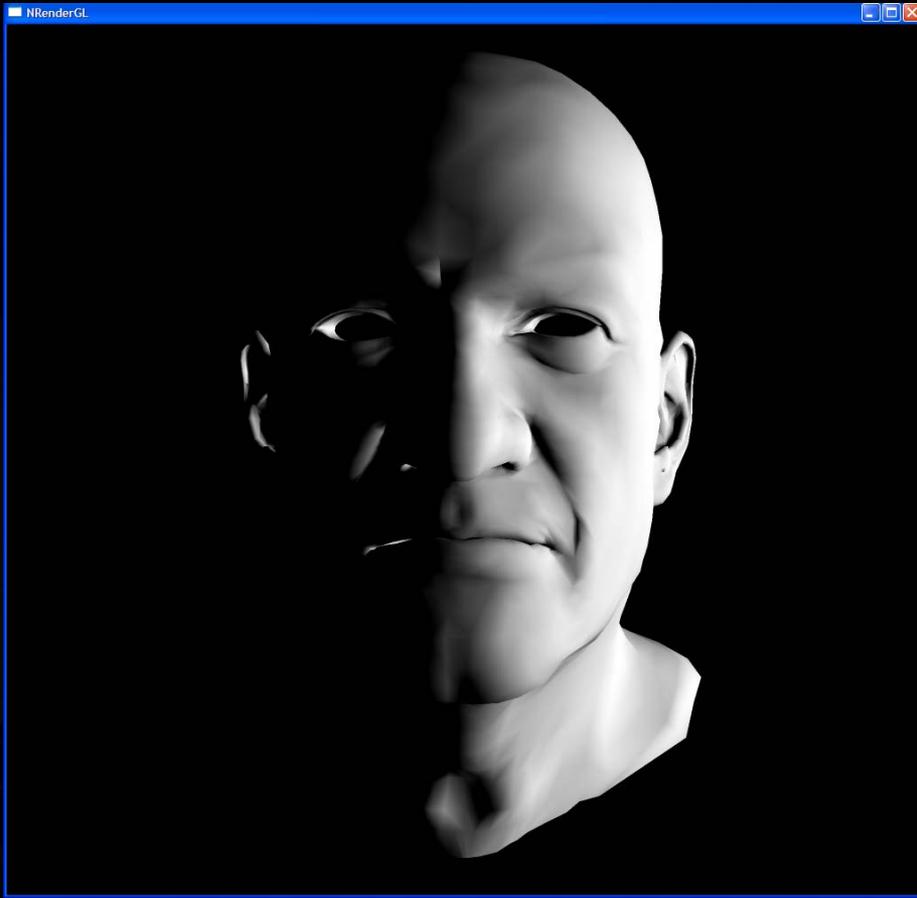


*Image: Ina Centaur*



Image: la.Chandra

# Texture-Space Diffusion



# Rendering using texture coordinates

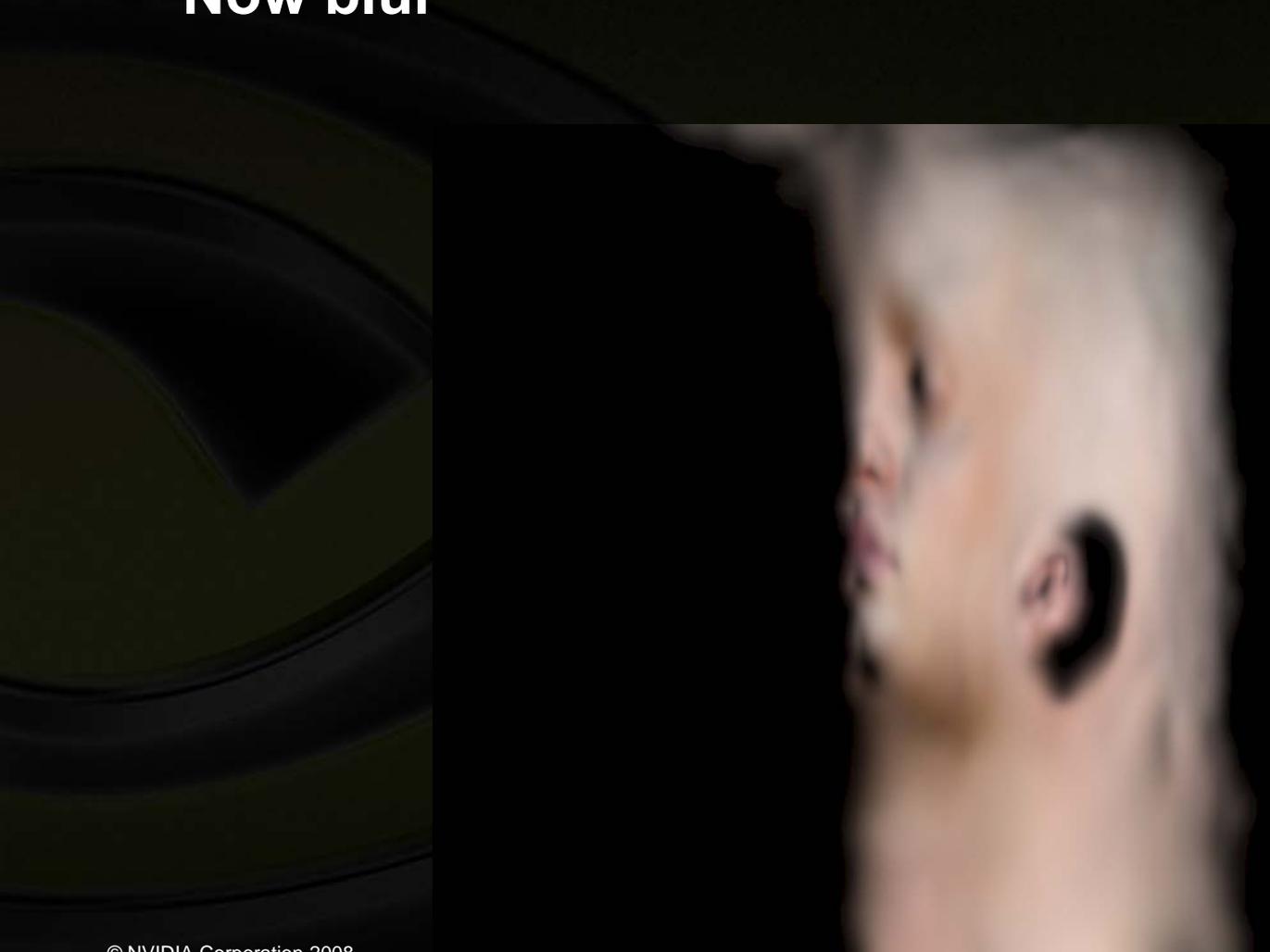
- First, render the surface diffuse lighting into an offscreen texture
- Instead of perspective positions, use surface (U,V)



# Blur lit surface texture



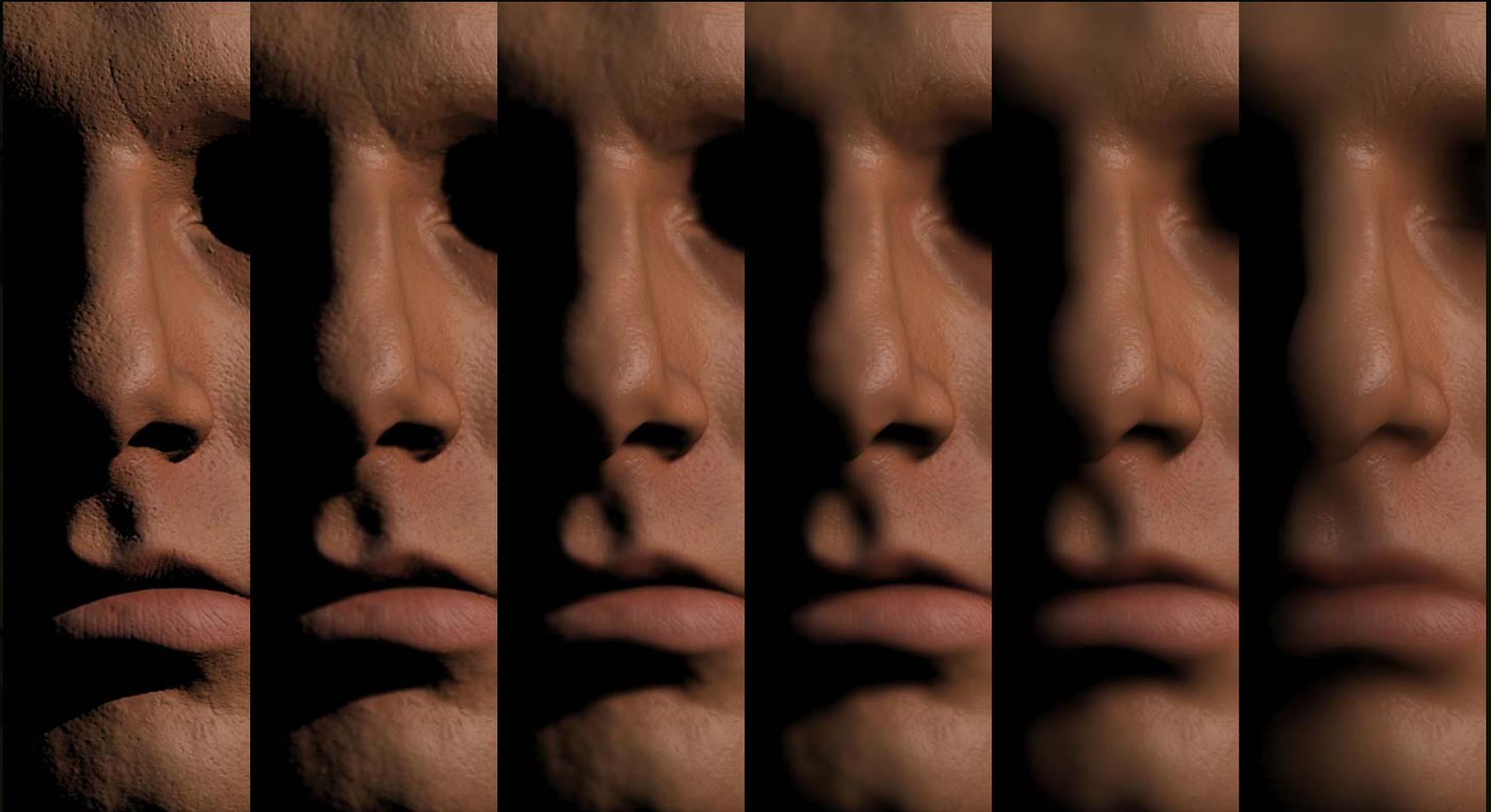
- Now blur



# Reapply in perspective



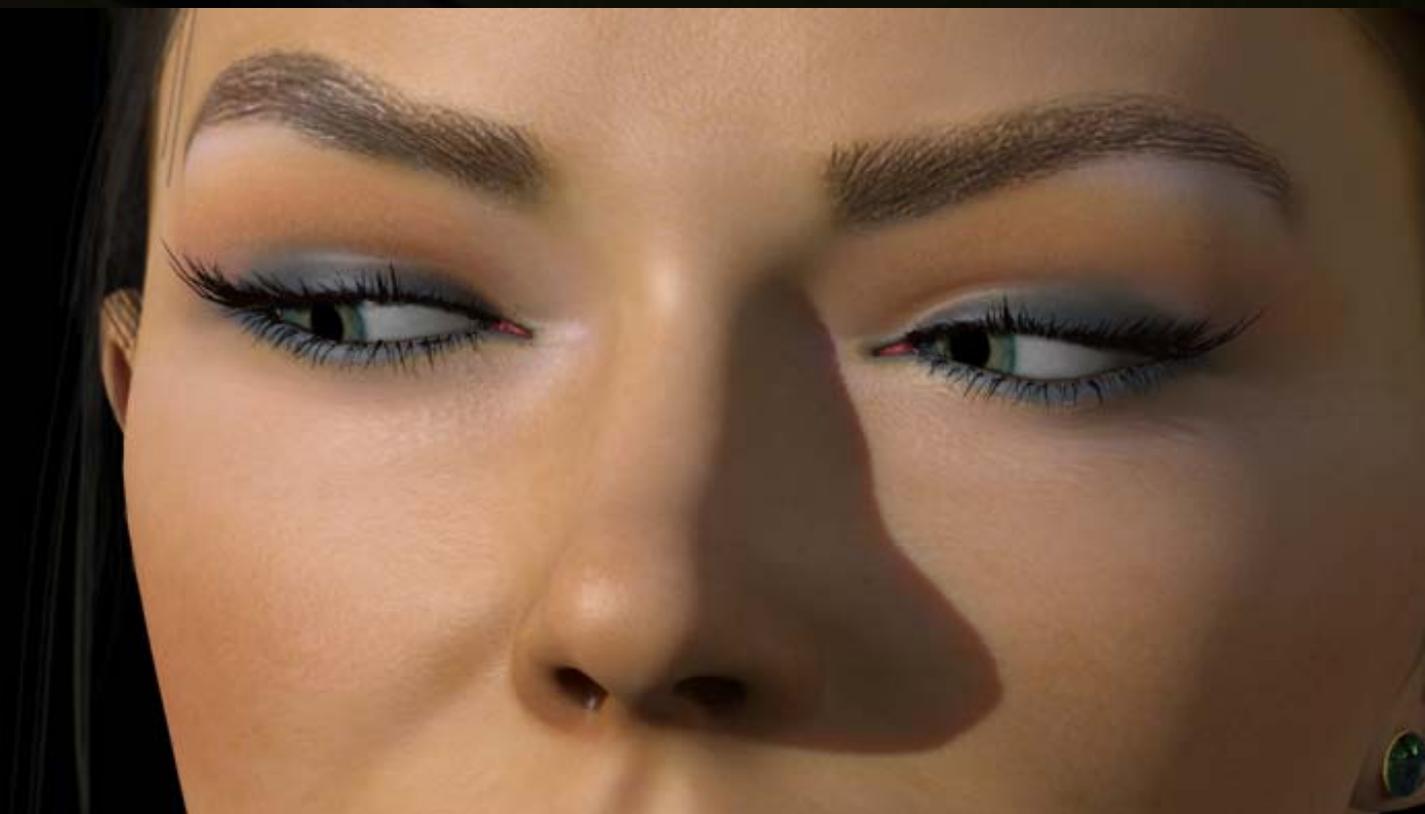
- Variations of unlit blur texture shown here



# Combine with “straight” lighting



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

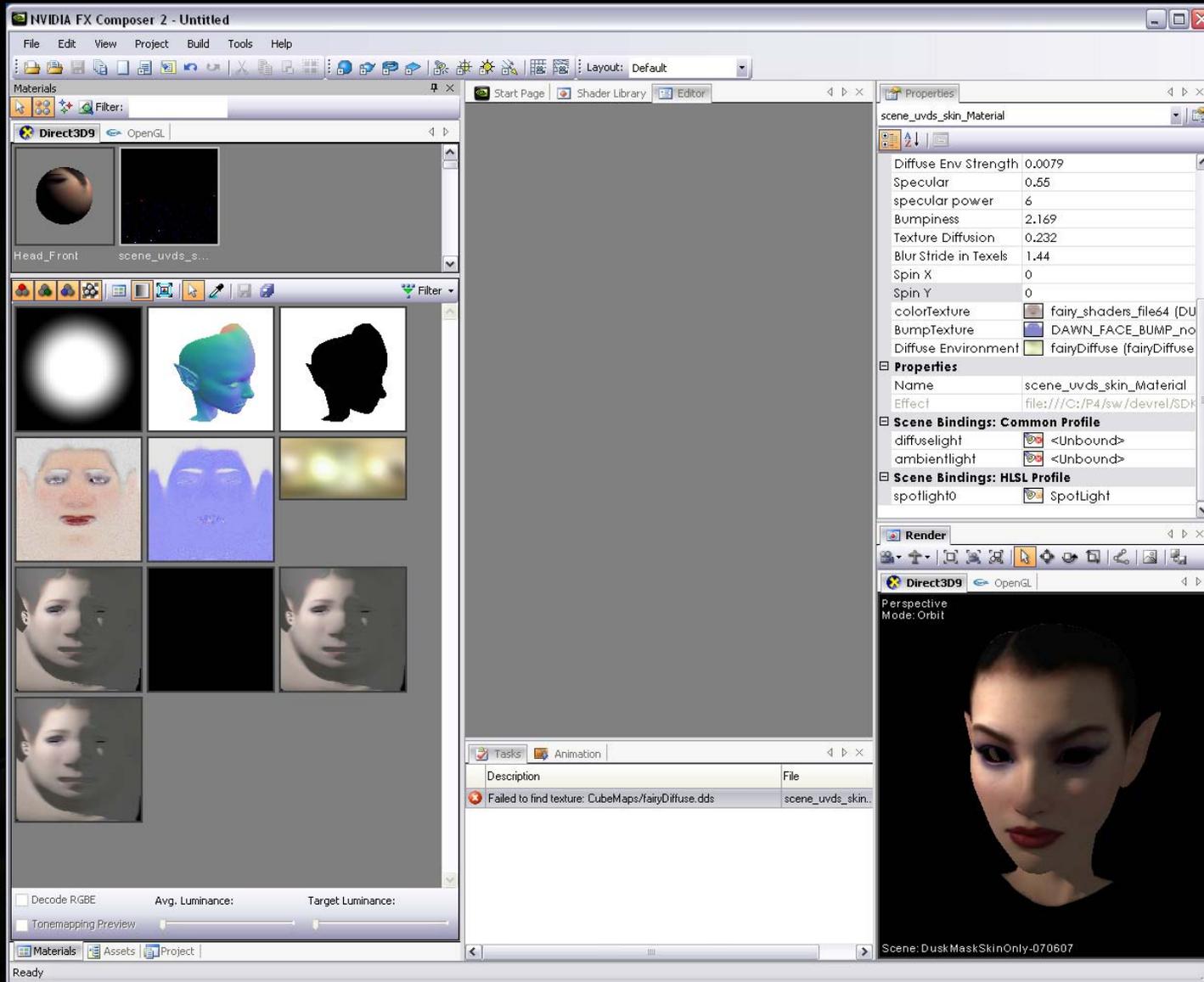


# The Mix Term



- 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:  
 $D = \text{diffuse lighting}$   
 $S = \text{specular lighting}$   
 $\text{Final\_Color} = (D^{(1.0-m)} * \text{blurred}(D^m)) + S$
- 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

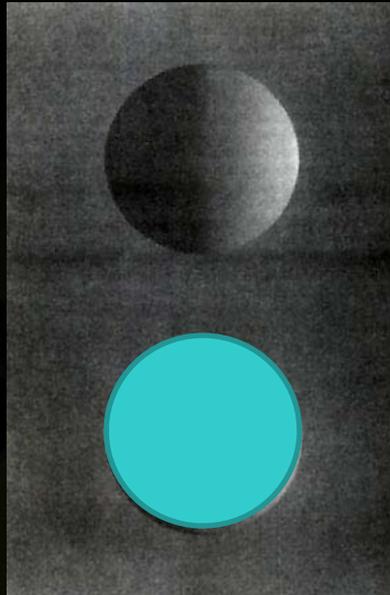
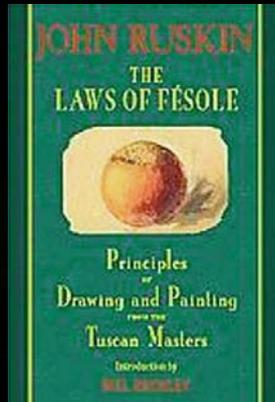
# Softimage FaceRobot

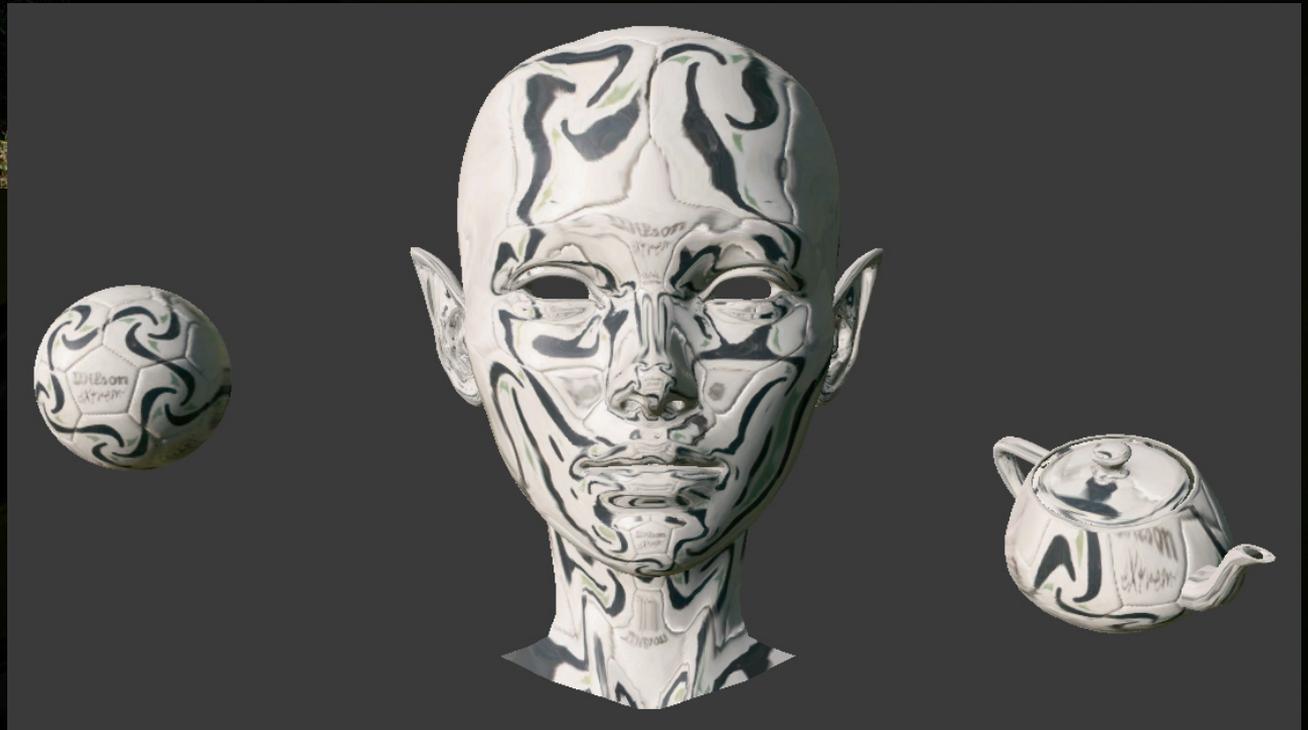
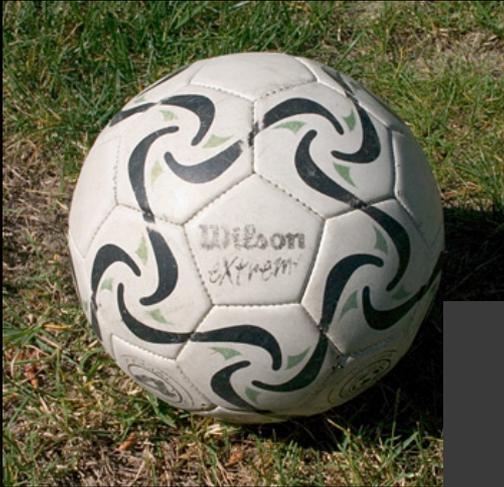


Another Brief Video Interlude...

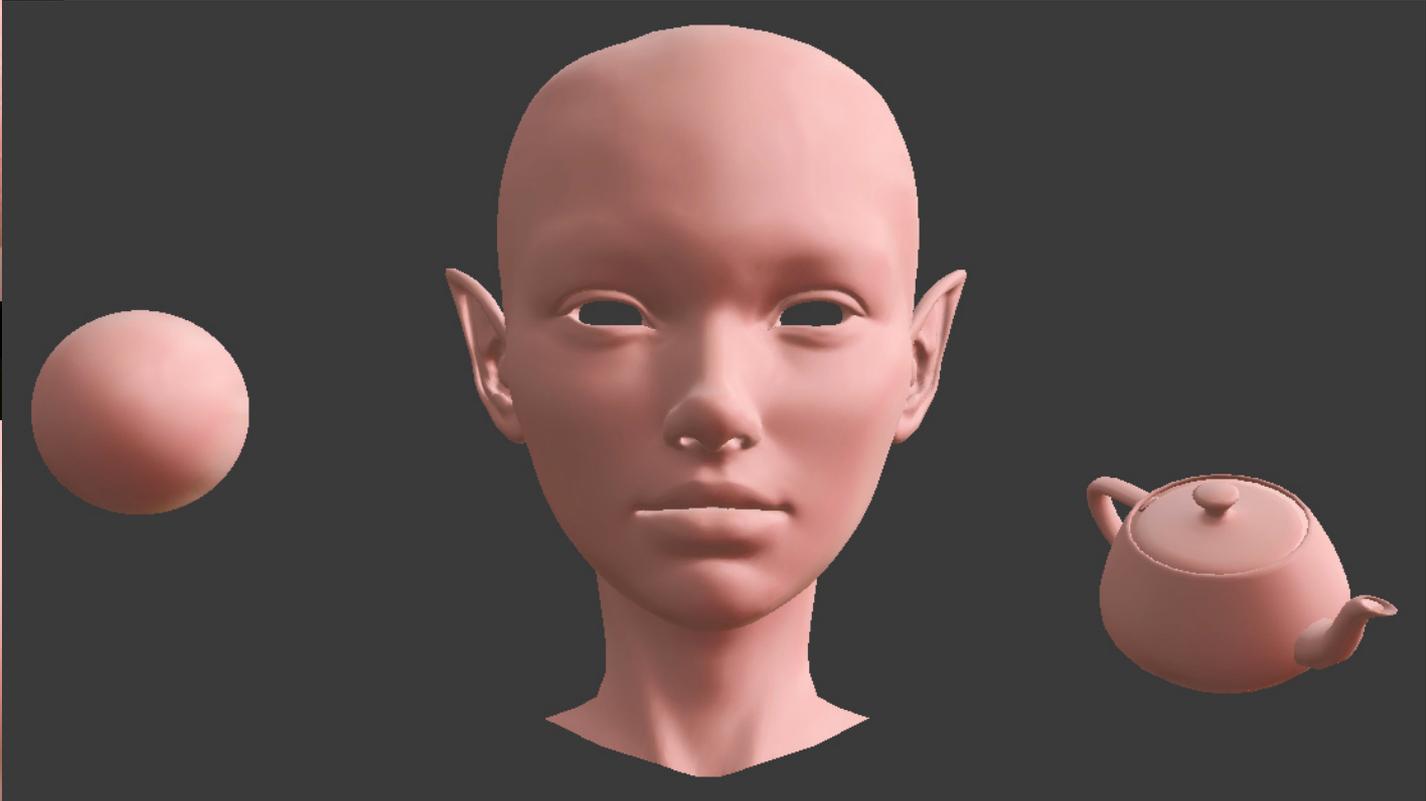
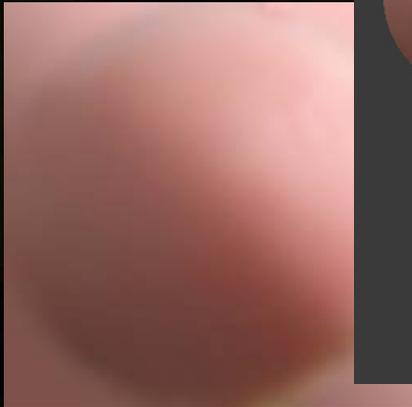


# Super-Cheap Skin (by accident)











*Image: Joshua Morane*

Image: Alexia Meili



Alexia

# Color Manipulations



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







*Image: Darks Adria*

# Shadows



# Shadows



*Second Life*



*Unreal Engine*



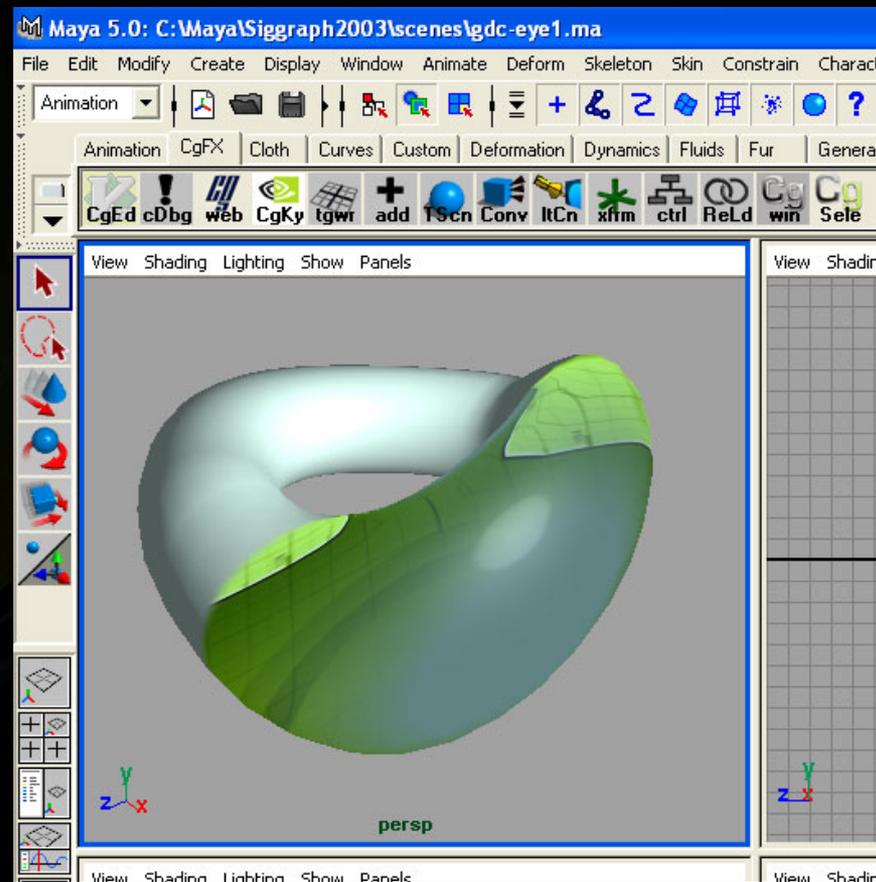
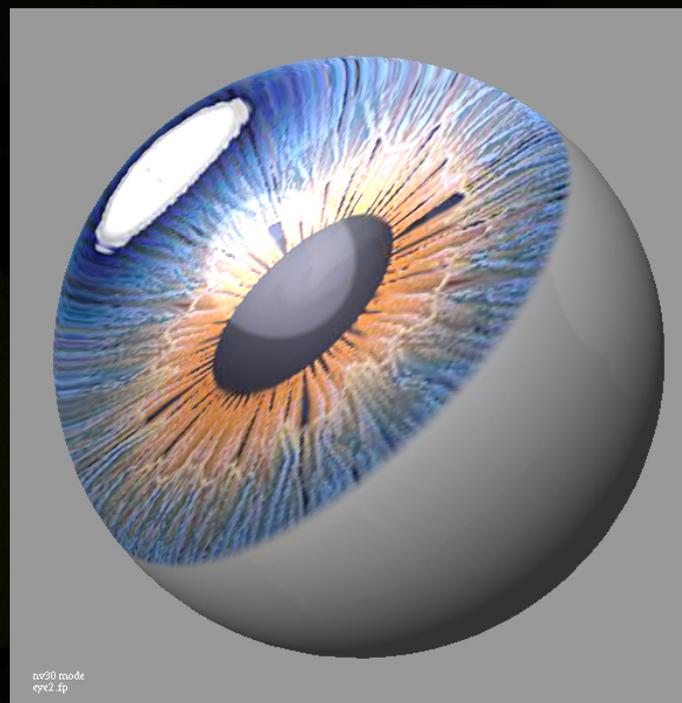
# Realism is a Tactic, Not a Goal



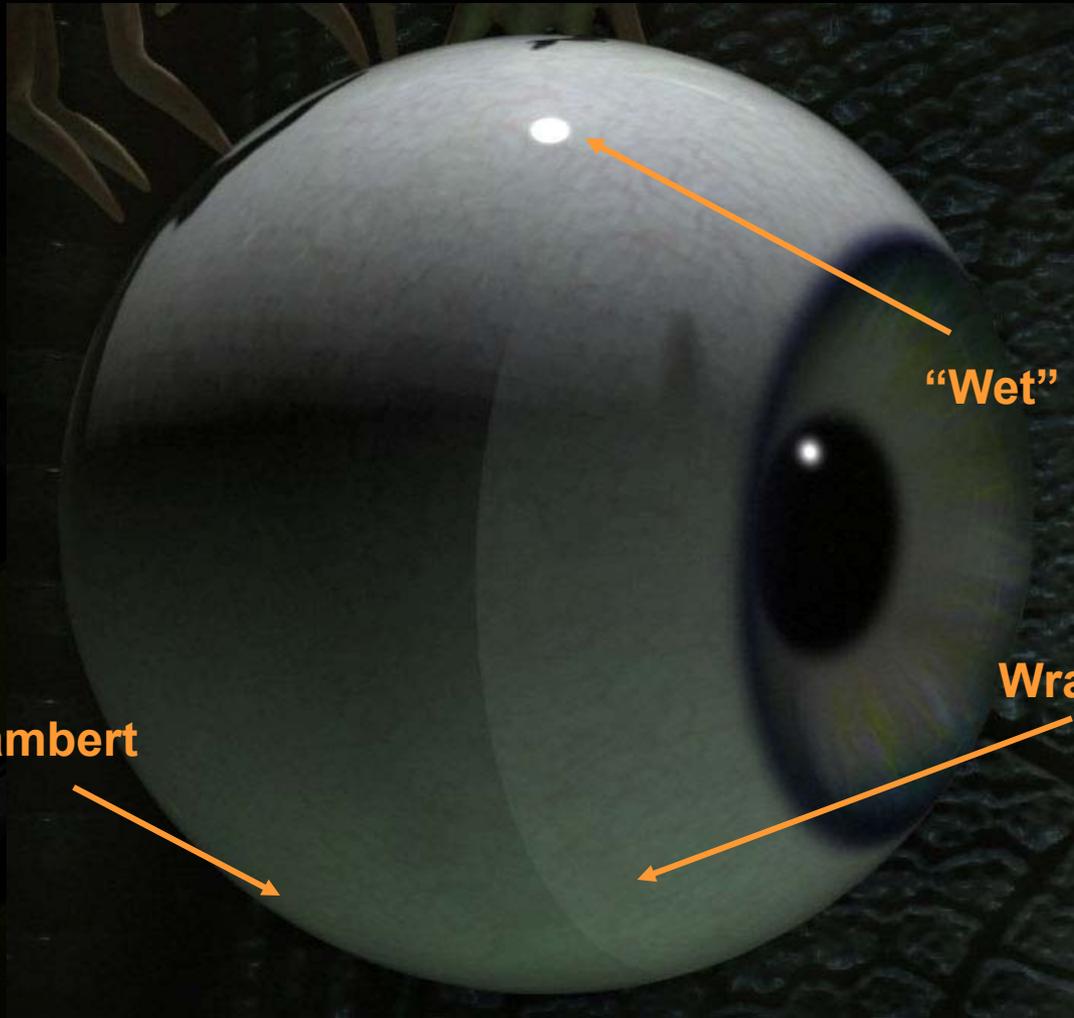
# A Thing of Beauty



# Making Better Eyes







**“Wet” highlight**

**Wrap-lighting of 0.2**

**Standard Lambert**

# Plus: bent shadows

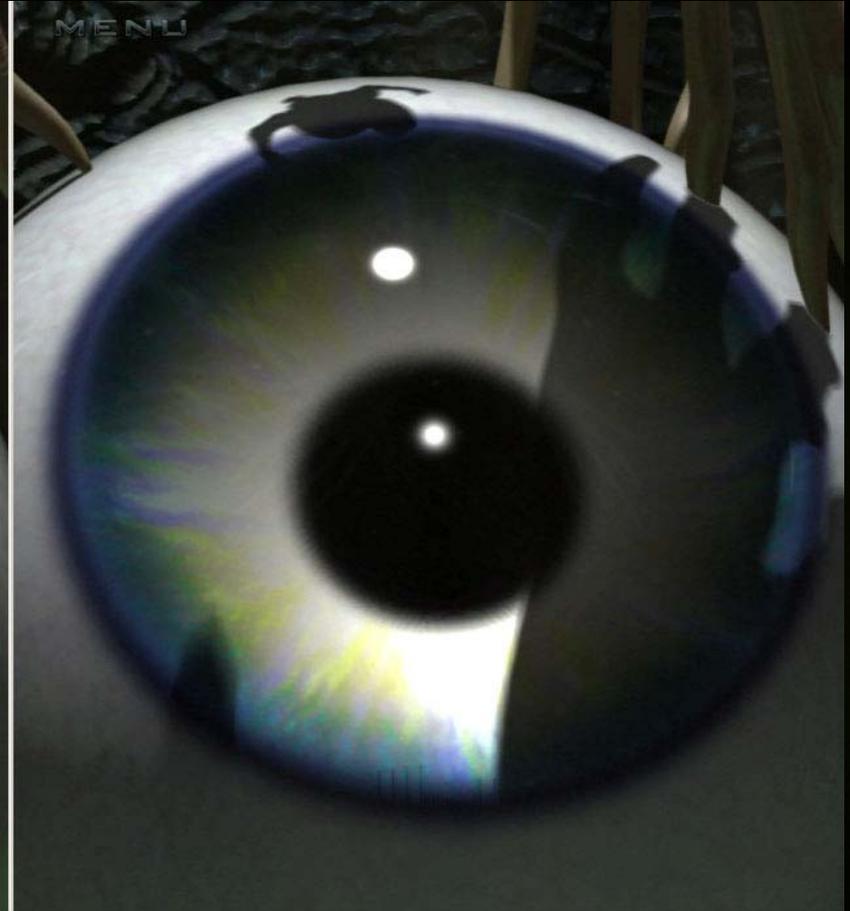
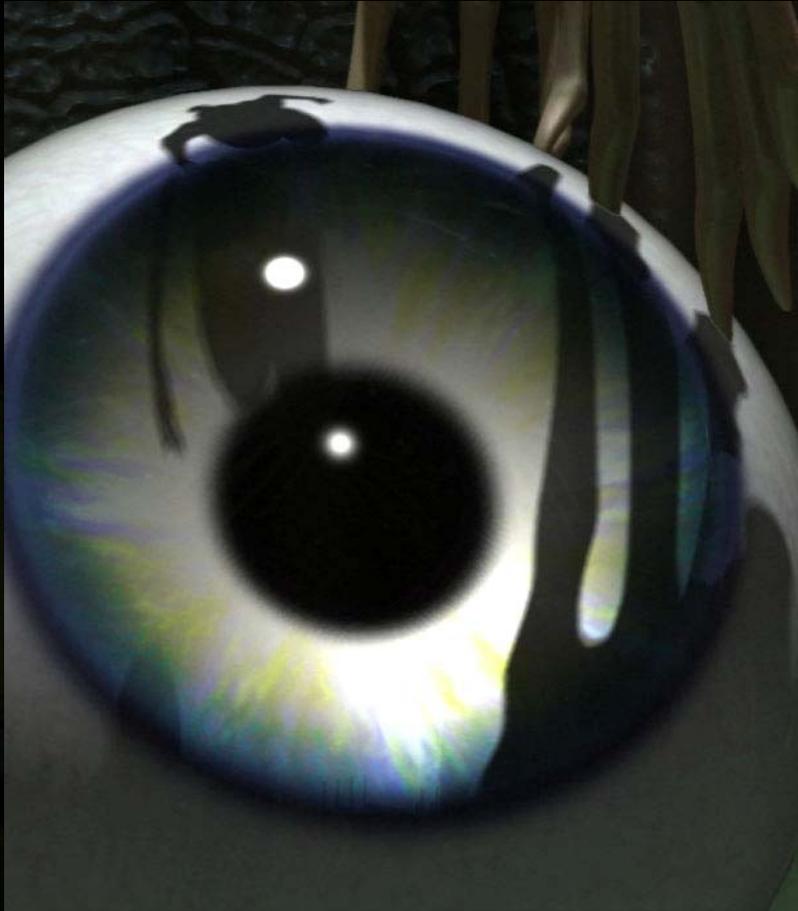




Image: Mia Olivier

# 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
- 2.1 Million triangles
- 24fps
- 8800GTX, 1280x1024
- 8xMSAA
- 2xSSAA with 5 taps



# Demo Time....



Toggle REF (F3)  
Change device (F2)  
Reset Simulation (F4)

Scene

- shadows
- simulate
- integrate
- addGravity
- curlyHair
- add forces
- linear stiffness
- 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

- use blurred density

Gaussian

Blur Radius: 5

Blur Sigma: 4.00

# Shading: Kajiya and Kay



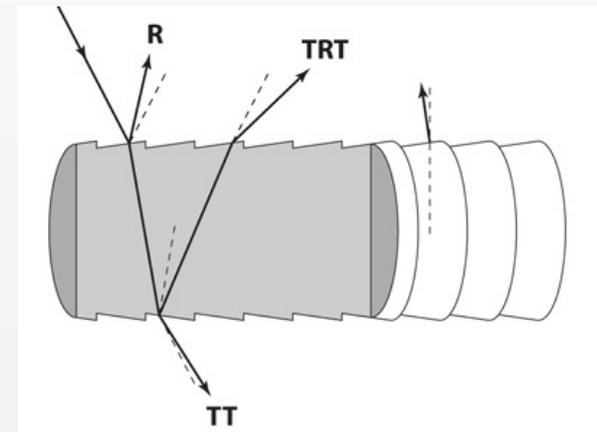
- Kajiya and Kay [*Rendering fur with three dimensional textures* (SIGGRAPH '89)]

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

- Ivan 2006

- fake dual specular highlights

- primary highlight shifted towards tip
- secondary highlight shifted towards root

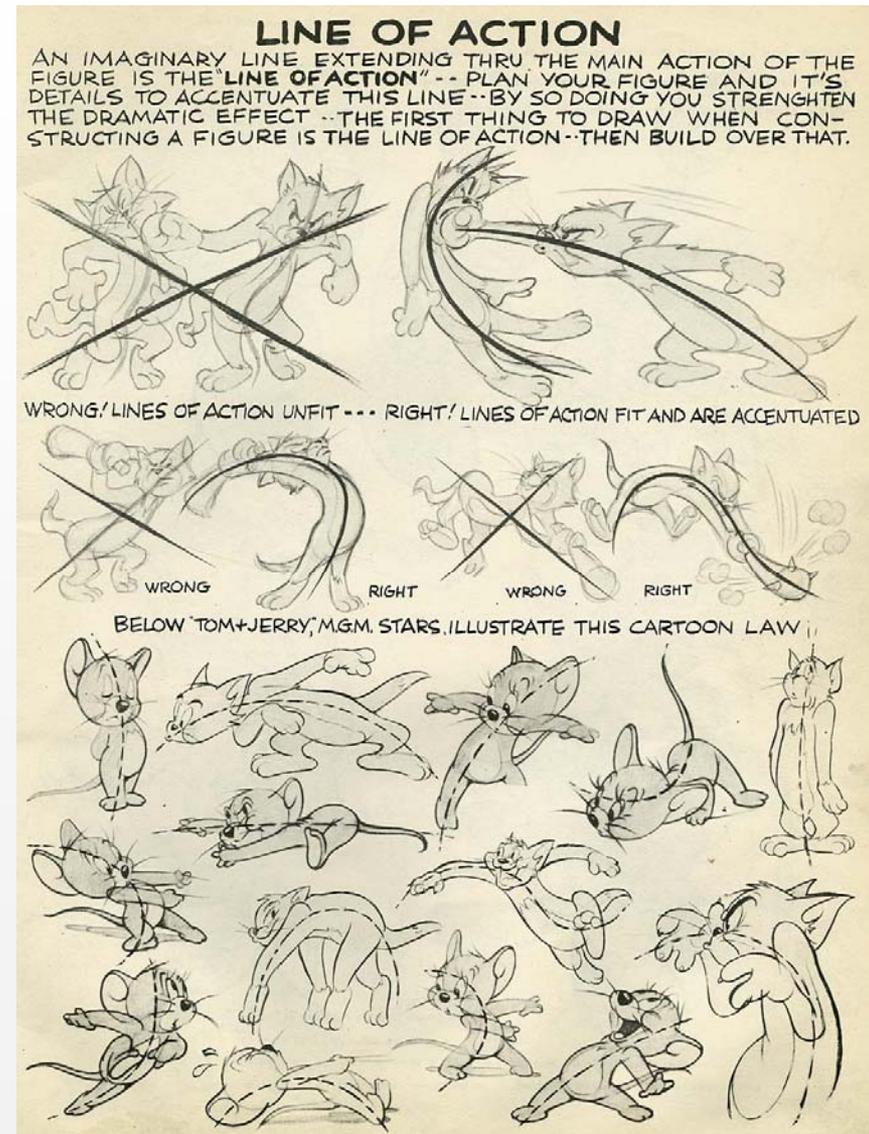


*"Ivan" model emulates  
Marchner "R" & "TRT" terms*

# 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!



# Similar Objects/Phenomena



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

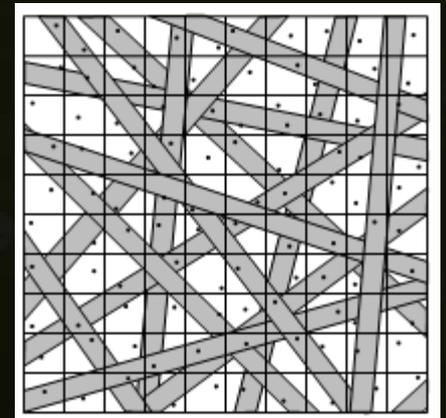


Image: Toko Voom

# Hair Shadowing Challenges



- **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



- **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



Toggle full screen

Toggle REF (F3)

Change device (F2)

NumTris: 678612

LightRes: 512x512

MultiLayerPCF

Opacity: 1.00



Num layers: 1



D3D10 69.19 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

MultiLayerPCF

Opacity: 1.00



Num layers: 1



# Regular PCF



- **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.**

D3D10 32.83 fps Vsync off (800x600, 16000000 UNIFORM (M34, Q16))  
HARDWARE: NVIDIA GeForce 8800 GTX



Toggle full screen

Toggle REF (F3)

Change device (F2)

NumTris: 678612

LightRes: 512x512

OpacityShMaps 

Opacity: 0.92



Slices: 32



Blur Radius: 5



# 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 introduce significant light bleeding. See next slide.**

D3D10 66.36 fps Vsync off (800x600), R8G8B8A8 UNORM, MSAA, C75  
HARDWARE: NVIDIA GeForce 8800 GTX



Toggle full screen

Toggle REF (F3)

Change device (F2)

NumTris: 678612

LightRes: 512x512

OpacityShMaps 

Opacity: 0.50



Slices: 32

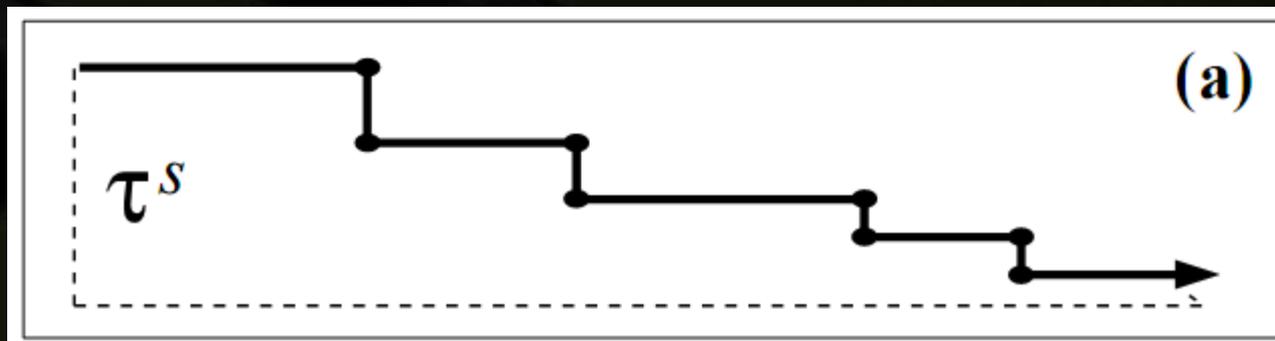


Blur Radius: 0



# Hair Transmittance

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



[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.**

D3D10 82.79 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

DeepShMaps

Opacity: 0.25



Filter Radius: 0



D3D10 20.17 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

DeepShMaps



Opacity: 0.50



Filter Radius: 2



# 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.**

D3D10 163.03 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

MultiLayerPCF

Opacity: 0.50



Num layers: 1



D3D10 108.47 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

MultiLayerPCF 

Opacity: 0.50



Num layers: 3



# 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  $\exp(-\sigma \cdot d)$  function.

D3D10 60.48 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: 0.50



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



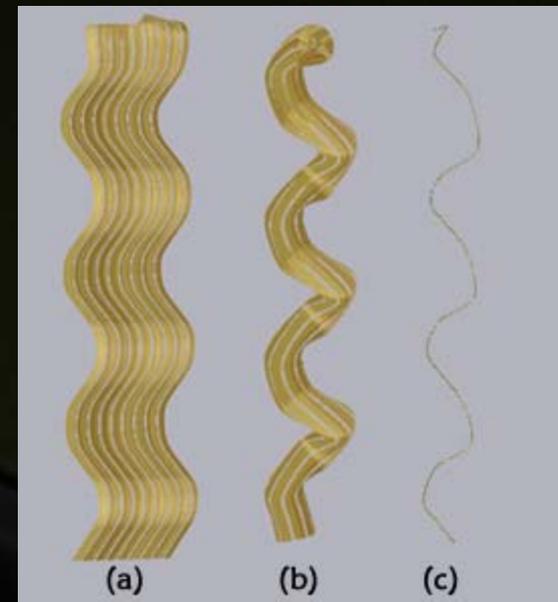


*Image: Iceykara*

# Another LOD Approach



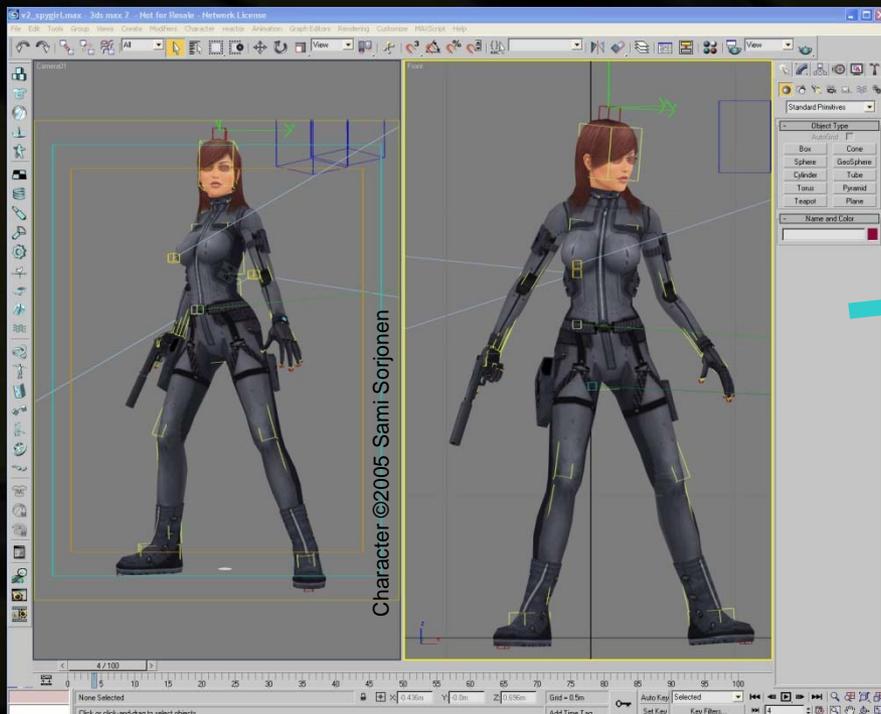
- **Ming & Ward: Multi-resolution Hair Modeling**
  - <http://www.cs.unc.edu/~geom/HSLOD/>
- **Hair is displayed either as a hierarchy of single strand, thinner or thicker structures**
- **Dynamically rearranged according to distance, visibility, and motion**



# SpyGirl: Enhancing Existing Assets



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



Simple Shaded View in 3DS Max



Output from FX Composer

# SpyGirl Shaders - Face



- **Skin: “subsurface scatter” simulation through diffuse rolloff of  $(N \cdot L)$** 
  - Similar to Dawn etc
- **Eyes: glossy highlight through thresholding**
  - Wide spec with a cutoff



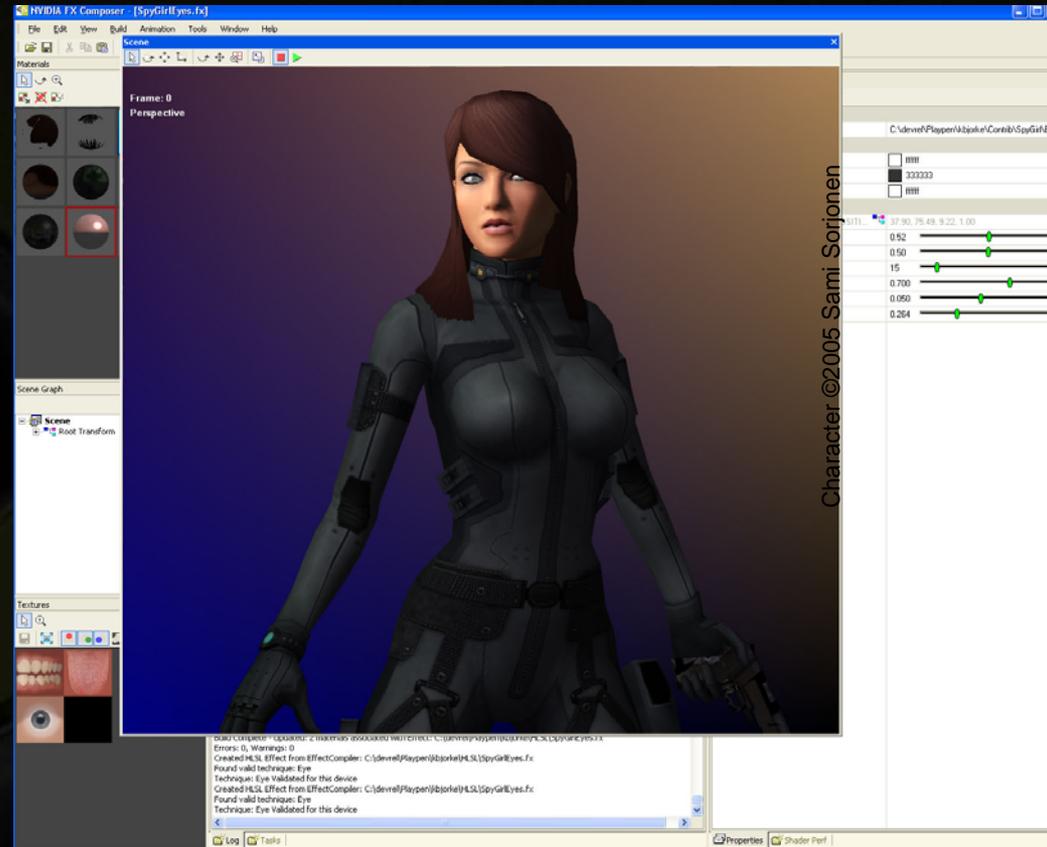
Red Subsurface Skin Shading & “Wet” Eye Shaders

# 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



We want to use Kajiya-Kay shading *without hair geometry*

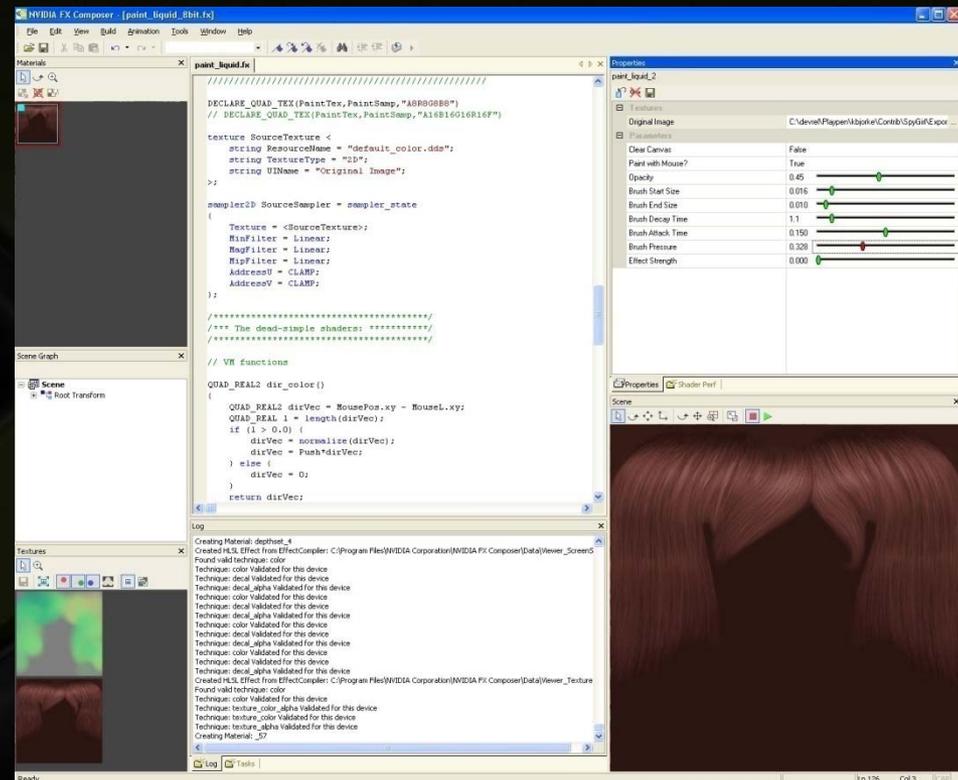
Here's Where We Break a Rule:

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**



**Color Map**



**Direction Map**

# Applying Kajiya-Kay to Hair Surface

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



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

**CGMILL.COM**

Character ©2005 Sami Sorjonen

# Special Thanks: Contributing Artists

*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

<http://www.flickr.com/photos/lunazolnir/>

Sixtine Karmin

<http://www.flickr.com/photos/25319917@N06/>

Phedre Dumouriez

<http://www.flickr.com/photos/fedry/>

Louise Numan / Dantalion Halberd

<http://www.flickr.com/photos/dantalion/>

Hiro Edelman

[http://www.flickr.com/photos/hiro\\_edelman/](http://www.flickr.com/photos/hiro_edelman/)

IceyKara

<http://www.flickr.com/photos/iceykara/>

Kean Kelly

<http://www.flickr.com/photos/keankelly/>

Prinz Photostudio

<http://www.flickr.com/photos/prinzphotostudio/>

F. Paine

<http://shootemup.hiconic.de/>

LunaRose Graves

[http://www.flickr.com/photos/lunarose\\_graves/](http://www.flickr.com/photos/lunarose_graves/)

la.Chandra

<http://www.flickr.com/photos/lachandra/>

Joshua Morane

[http://www.flickr.com/photos/last\\_exit/](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/](http://www.flickr.com/photos/deedee_deepdene/)

Mia Olivier

[http://www.flickr.com/photos/mia\\_olivier/](http://www.flickr.com/photos/mia_olivier/)

Axelia Meili

<http://www.flickr.com/photos/25200771@N04/>

·СЯФШ·

<http://www.mydarkesthour.net/>

ColeMarie Soleil

<http://www.flickr.com/photos/rockerfaerie/>

Connie Sec

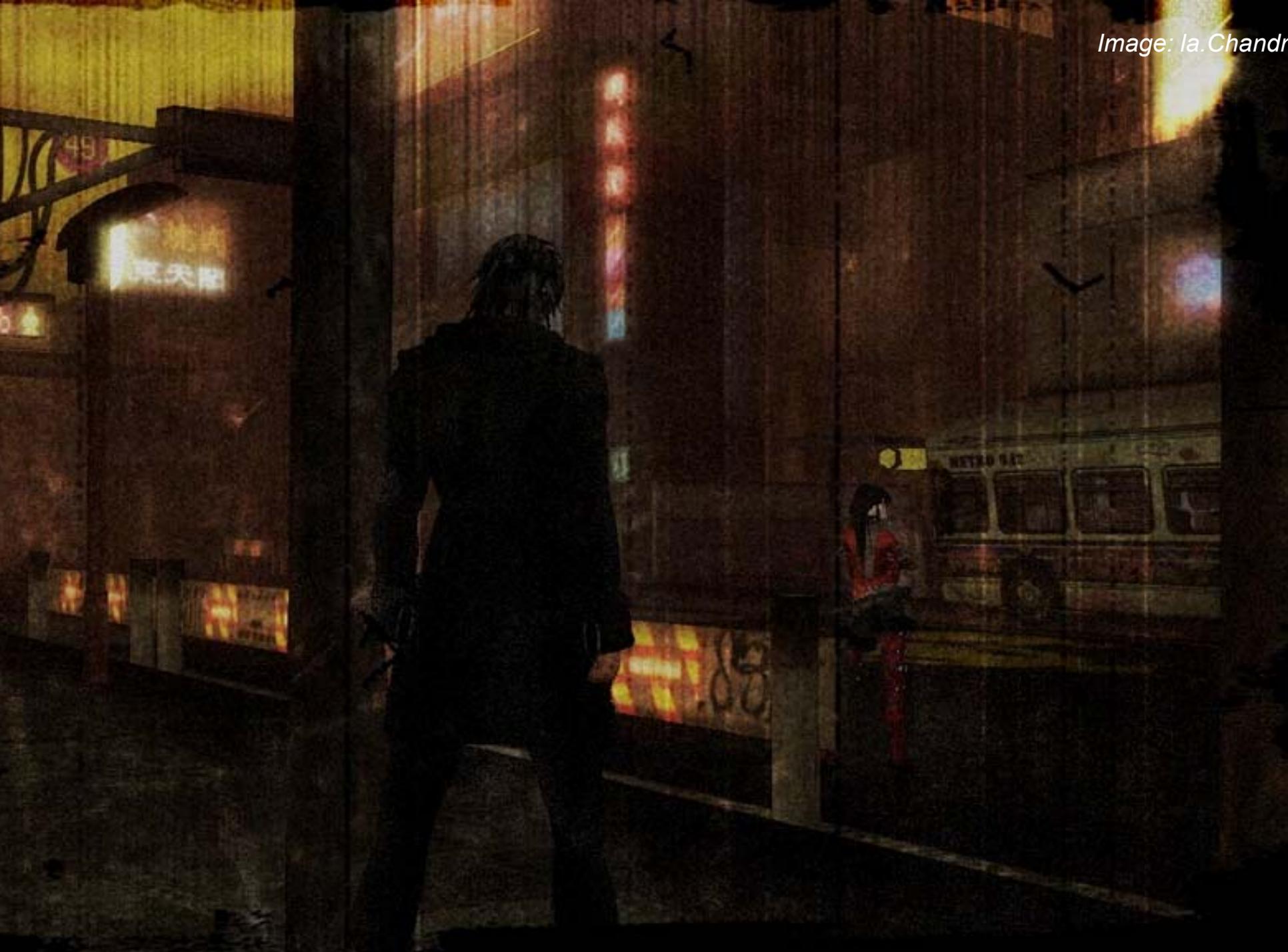
<http://www.flickr.com/photos/conniesec/>

Darks Adria

<http://www.flickr.com/photos/22383183@N06/>

Gita Rau

<http://www.flickr.com/photos/gitarau/>



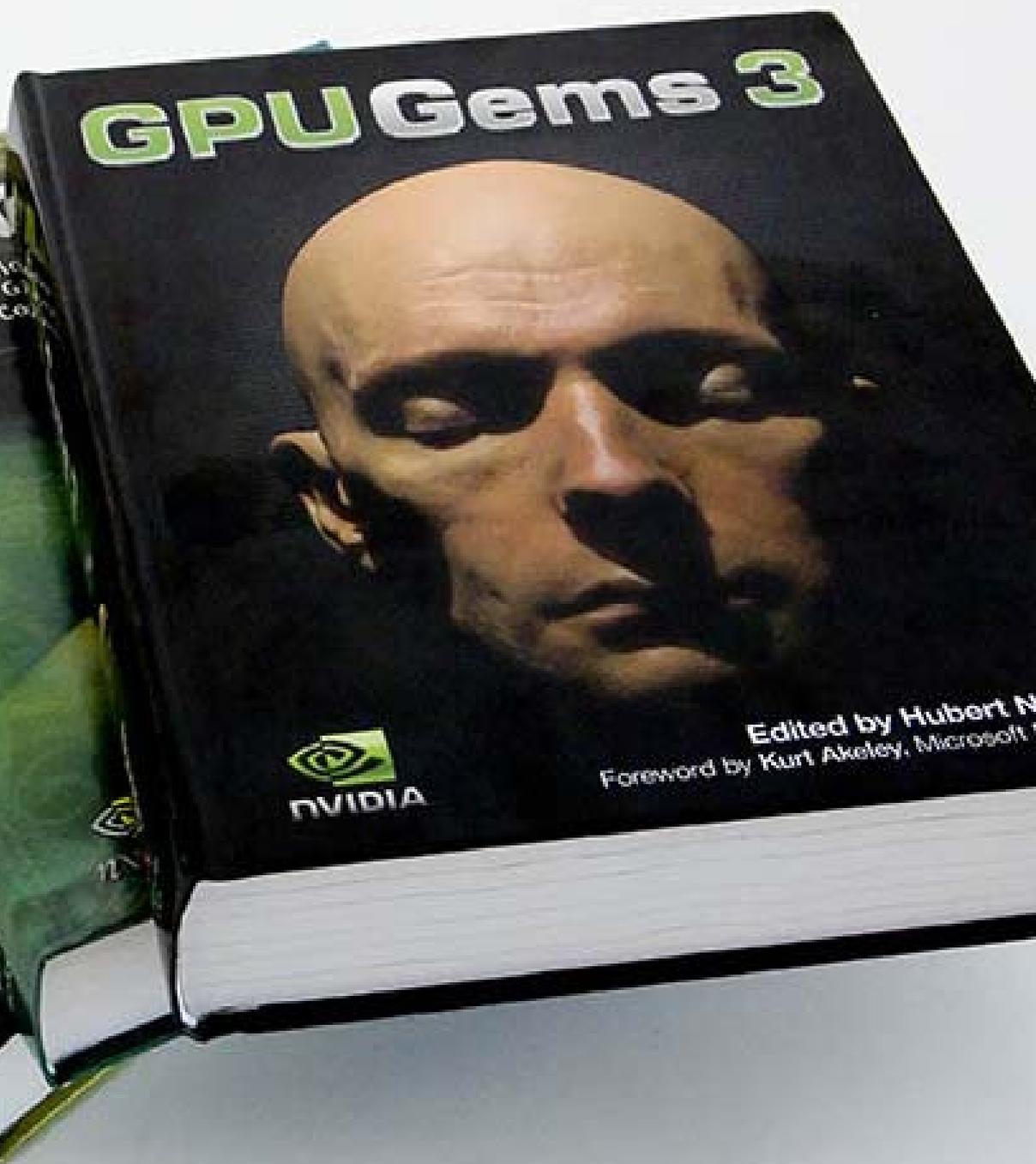
"If you deliberately set out to be less than you are capable, you'll be unhappy for the rest of your life."

*Abraham Maslow*

# Q & A

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







**nVISION 08**  
THE WORLD OF VISUAL COMPUTING

<http://developer.nvidia.com/>