ILLUSTRATIVE RENDERING IN TEAM FORTRESS 2

Jason Mitchell Moby Francke Dhabih Eng



OUTLINE

- Motivations and related work
- Environments
- Characters and interactive shading
- Future work

TEAM FORTRESS 2

- Class-based multiplayer combat game which will be released this fall
- Unique visual style
 - **Differentiation** multiplayer combat games tend to embrace a contemporary photorealistic look
 - Gameplay -Team Fortress has always featured cartoonish, over-the-top situations
 - Readability Class differentiation is the core of *Team Fortress 2*, hence we needed to be able to clearly differentiate classes visually



ENVIRONMENT DESIGN PRINCIPLES

- Value contrast
- Simple forms
 - No unnecessarily off-kilter shapes
- Minimize visual noise
 - Texture and geometric
 - Minimize repetition





CONTRASTING TEAM PROPERTIES

- Red
 - Warm colors
 - Natural materials
 - Angular geometry
- Blue
 - Cool colors
 - Industrial materials
 - Orthogonal forms





BLUE BASE IN 2FORT MAP



RED BASE IN 2FORT MAP



WORLD RENDERING

- Photorealistic techniques from our other games
 - Radiosity-generated light maps
 - Special effects such as reflection and refraction
- Hand-painted textures with minimal noise, applied directly to 3D geometry
 - Loose details with visible brush strokes
 - Inherent solidity and frame-to-frame coherence
 - Hold up under magnification better than photoreference
- Brush strokes appear in perspective, not in the 2D image plane [Miyazaki02]
- High frequency detail in photorealistic games can overpower design



Color Palette

MIYAZAKI - BRUSH WIDTH FORESHORTENED



 Can easily imagine a 3D camera move between these 2D views of the same space



NEUTRAL ENTITIES

- Variations in hue and saturation are used to differentiate neutral entities in the game world
 - A hue other than red or blue creates disassociation from either team color
 - Increased saturation makes these important entities stand out in the desaturated environment
- Equally beneficial or dangerous to either team
 - Beneficial green / cyan health pickups
 - Dangerous yellow train yard gates









CHARACTER DESIGN GOALS

- Easily visible against environment
- Characters must be readable quickly by other players
- Communicate shape via shading and silhouette under all lighting conditions



GOOCH, 1998

- Hue and luminance shifts indicate surface orientation relative to light
- Blend between warm and cool based upon unclamped Lambertian term, underlying albedo and some free parameters
- Extreme lights and darks are reserved for edge lines and highlights



 $\left(\frac{1}{2}\left(\hat{n}\cdot\hat{l}\right)+\frac{1}{2}\right)\left(k_{blue}+\alpha k_{d}\right)+\left(1-\left(\frac{1}{2}\left(\hat{n}\cdot\hat{l}\right)+\frac{1}{2}\right)\right)\left(k_{yellow}+\beta k_{d}\right)$

LAKE, 2000

- Lake used a 1D texture lookup based upon the Lambertian term to simulate the limited color palette cartoonists use for painting cels
- Also allows for the inclusion of a view-independent pseudo specular highlight by including a small number of bright texels at the "lit" end of the 1D texture map





BARLA, 2006

- Barla has extended this technique by using a 2D texture lookup to incorporate view-dependent and level-of-detail effects.
- Fresnel-like creates a hard "virtual backlight" which is essentially a rim-lighting term, though this term is not designed to correspond to any particular lighting environment.



EARLY 20TH CENTURY COMMERCIAL ILLUSTRATION

- Chose to adopt specific conventions of the commercial illustrator J. C. Leyendecker:
 - Shading obeys a warm-to-cool hue shift. Shadows go to cool, not black
 - Saturation increases at the terminator with respect to a given light source. The terminator is often reddened.
 - On characters, interior details such as clothing folds are chosen to echo silhouette shapes
 - Silhouettes are often emphasized with rim highlights rather than dark outlines



J.C. Leyendecker Arrow collar advertisement, 1929 J.C. Leyendecker *Swimmin' Hole*, 1935



J.C. Leyendecker *Thanksgiving* 1628-1928

J.C. Leyendecker *Tally-Ho*, 1930

ENGINEER CONCEPT



RIM HIGHLIGHTING: BEFORE



RIM HIGHLIGHTING: AFTER





- Players must be able to quickly identify other players by team, class and selected weapon at a variety of distances and viewpoints
- We think of this in terms of a visual "read hierarchy"
- Design Goals
 - Team Friend or Foe?
 - Color
 - Class Run or Attack?
 - Distinctive silhouettes
 - Body proportions
 - Weapons
 - Shoes, hats and clothing folds
 - Selected weapon What's he packin'?
 - Highest contrast at chest level, where weapon is held
 - Gradient from dark feet to light chest



Color Palette

CHARACTER LIGHTING EQUATION

VIEW INDEPENDENT
$$k_{d} \left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w \left(\left(\alpha \left(\hat{n} \cdot \hat{l}_{i} \right) + \beta \right)^{\gamma} \right) \right] + k_{d} \left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w \left(\left(\alpha \left(\hat{n} \cdot \hat{l}_{i} \right) + \beta \right)^{\gamma} \right) \right] \right]$$

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

VIEW-DEPENDENT

$$k_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha\left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{\gamma}\right)\right]$$

• Spatially-varying directional ambient





$$k_{d}\left[a(\hat{n})+\sum_{i=1}^{L}c_{i}w\left(\left(\alpha\left(\hat{n}\cdot\hat{l}_{i}\right)+\beta\right)^{*}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms

$$k_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha \left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{\gamma}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term



$$k_d \left[a(\hat{n}) + \sum_{i=1}^{L} c_i w \left(\left(\alpha \left(\hat{n} \cdot \hat{l}_i \right) + \beta \right)^r \right) \right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term
 - Scale, bias and exponent



$$k_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha\left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{*}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term
 - Scale, bias and exponent
 - Warping function





$$k_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha\left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{\gamma}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term
 - Scale, bias and exponent
 - Warping function



$$\mathbf{x}_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha\left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{\gamma}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term
 - Scale, bias and exponent
 - Warping function
- Albedo



$$k_{d}\left[a(\hat{n}) + \sum_{i=1}^{L} c_{i} w\left(\left(\alpha\left(\hat{n} \cdot \hat{l}_{i}\right) + \beta\right)^{\gamma}\right)\right]$$

- Spatially-varying directional ambient
- Modified Lambertian terms
 - Unclamped Lambertian term
 - Scale, bias and exponent
 - Warping function
- Albedo

AMBIENT CUBE

- Grounds characters in game worlds
- Pre-compute irradiance samples throughout the environment
- Variable density *irradiance volume* [Greger98] where each sample defines an irradiance environment map [Ramamoorthi01]
- Directional ambient term which includes only indirect light
- Lights beyond the first four can be added to the ambient cube
- Used in a novel way in rim lighting, which we'll discuss in a moment

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

• Multiple Phong terms per light

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s (\hat{v} \cdot \hat{r}_i)^{k_{spec}}, f_r k_r (\hat{v} \cdot \hat{r}_i)^{k_{rim}} \right) \right] + (\hat{n} \cdot \hat{u}) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - a(v) Directional ambient evaluated with v

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_{s} artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - *a*(*v*) Directional ambient evaluated with *v*
 - k_r same rim mask

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - a(v) Directional ambient evaluated with v
 - k_r same rim mask
 - f_r same rim Fresnel

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - a(v) Directional ambient evaluated with v
 - k_r same rim mask
 - f_r same rim Fresnel
 - $n \cdot u$ term that makes rim highlights tend to come from above (*u* is up vector)

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - a(v) Directional ambient evaluated with v
 - k_r same rim mask
 - f_r same rim Fresnel
 - $n \cdot u$ term that makes rim highlights tend to come from above (*u* is up vector)

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - a(v) Directional ambient evaluated with v
 - k_r same rim mask
 - f_r same rim Fresnel
 - $n \cdot u$ term that makes rim highlights tend to come from above (*u* is up vector)

$$\sum_{i=1}^{L} \left[c_i k_s max \left(f_s \left(\hat{v} \cdot \hat{r}_i \right)^{k_{spec}}, f_r k_r \left(\hat{v} \cdot \hat{r}_i \right)^{k_{rim}} \right) \right] + \left(\hat{n} \cdot \hat{u} \right) f_r k_r a(\hat{v})$$

- Multiple Phong terms per light
 - k_{rim} broad, constant exponent
 - k_{spec} exponent (constant or texture)
 - f_s^{por} artist tuned Fresnel term
 - f_r rim Fresnel term, $(1-(n\cdot v))^4$
 - k_r rim mask texture
 - k_s specular mask texture
- Dedicated rim lighting
 - *a*(*v*) Directional ambient evaluated with *v*
 - k_r same rim mask
 - f_r same rim Fresnel
 - $n \cdot u$ term that makes rim highlights tend to come from above (*u* is up vector)

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]

[Heidrich98]

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]

FUTURE WORK

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]
 - Shaping highlights [Anjyo03]

FUTURE WORK

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]
 - Shaping highlights [Anjyo03]
- More reliable rim term

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]
 - Shaping highlights [Anjyo03]
- More reliable rim term
- Image-space contrast enhancement [Luft06]

[Luft06]

 $\ensuremath{\textcircled{}}$ C 2007 Valve Corporation. All Rights Reserved.

FUTURE WORK

- More flexible specular
 - Anisotropic highlights [Heidrich98] [Gooch98]
 - Shaping highlights [Anjyo03]
- More reliable rim term
- Image-space contrast enhancement [Luft06]
- Abstracted shadows [DeCoro07]

CONCLUSION

- Motivations and related work
- Environments
- Characters and interactive shading
- Future work

