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

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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
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

\[
\left(\frac{1}{2} (\hat{n} \cdot \hat{l}) + \frac{1}{2}\right)(k_{\text{blue}} + \alpha k_d) + \left(1 - \left(\frac{1}{2} (\hat{n} \cdot \hat{l}) + \frac{1}{2}\right)\right)\left(k_{\text{yellow}} + \beta k_d\right)
\]
• 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
Rim Highlights

J.C. Leyendecker
Arrow collar advertisement, 1929

Red Terminator

J.C. Leyendecker
Swimmin’ Hole, 1935

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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
CHARACTER LIGHTING EQUATION

VIEW INDEPENDENT

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

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

VIEW-DEPENDENT
VIEW INDEPENDENT TERMS

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

- Spatially-varying directional ambient
\[ k_d \left[ a(\hat{n}) + \sum_{i=1}^{L} c_i w \left( (\alpha (\hat{n} \cdot \hat{l}_i) + \beta)^\gamma \right) \right] \]

- Spatially-varying directional ambient
- Modified Lambertian terms
VIEW INDEPENDENT TERMS

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

- Spatially-varying directional ambient
- Modified Lambertian terms
  - Unclamped Lambertian term
**VIEW INDEPENDENT TERMS**

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

- Spatially-varying directional ambient
- Modified Lambertian terms
  - Unclamped Lambertian term
  - Scale, bias and exponent
\[ k_d \left[ a(\hat{n}) + \sum_{i=1}^{L} c_i w\left( (\alpha (\hat{n} \cdot \hat{i}) + \beta)^y \right) \right] \]

- Spatially-varying directional ambient
- Modified Lambertian terms
  - Unclamped Lambertian term
  - Scale, bias and exponent
  - Warping function
- \[ \frac{1}{2} (\hat{n} \cdot \hat{i}) + \frac{1}{2} \]
VIEW INDEPENDENT TERMS

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

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- Albedo
View Independent Terms

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- Modified Lambertian terms
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  - Scale, bias and exponent
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- 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
\[
\sum_{i=1}^{L} \left[ c_i k_s \max \left( f_s (\hat{\nu} \cdot \hat{r}_i)^{k_{\text{spec}}} , f_r k_r (\hat{\nu} \cdot \hat{r}_i)^{k_{\text{rim}}} \right) \right] + (\hat{n} \cdot \hat{u}) f_r k_r a(\hat{\nu})
\]
\[ \sum_{i=1}^{L} [c_i k_s \max(f_s (\hat{\nu} \cdot \hat{r}_i)^{k_{spec}}, f_r k_r (\hat{\nu} \cdot \hat{r}_i)^{k_{rim}})] + (\hat{n} \cdot \hat{u}) f_r k_r a(\hat{v}) \]

- Multiple Phong terms per light
VIEW-DEPENDENT TERMS

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

- Multiple Phong terms per light
  - \( k_{\text{rim}} \) broad, constant exponent
VIEW-DEPENDENT TERMS

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- Multiple Phong terms per light
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  - \( f_s \): artist tuned Fresnel term

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View-Dependent Terms

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

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  - \( k_r \) rim mask texture
VIEW-DEPENDENT TERMS

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VIEW-DEPENDENT TERMS

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  - \( k_r \) rim mask texture
  - \( k_s \) specular mask texture
- Dedicated rim lighting
  - \( a(v) \) Directional ambient evaluated with \( v \)
VIEW-DEPENDENT TERMS

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

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  - $k_{\text{rim}}$ broad, constant exponent
  - $k_{\text{spec}}$ 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
  - $a(\nu)$ Directional ambient evaluated with $\nu$
  - $k_r$ same rim mask
View-Dependent Terms

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

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  - \( f_r \) same rim Fresnel
VIEW-DEPENDENT TERMS

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- **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)
**VIEW-DEPENDENT TERMS**

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\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] + (\hat{n} \cdot \hat{u}) f_r k_r a(\hat{v})
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FUTURE WORK

• More flexible specular
  • Anisotropic highlights [Heidrich98] [Gooch98]
FUTURE WORK

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**FUTURE WORK**

- More flexible specular
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  - Shaping highlights [Anjyo03]
FUTURE WORK

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- Image-space contrast enhancement [Luft06]
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