

Alguns Conceitos Iluminação Global

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UFPE

1 revisão maio/2009

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Síntese de Imagens Realísticas

- Um dos tópicos mais importantes da CG
- Cenas do mundo real são complexas
 - Geometria
 - Materiais
 - Luz
 - Transporte

2

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Síntese de Imagens Realísticas

- Geometria
- Materiais
- Luz
- Transporte



Imagens de Manuel Oliveira

3

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Síntese de Imagens Realísticas

- Geometria
- Materiais
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4

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Síntese de Imagens Realísticas

- Geometria
- Materiais
- Luz
- Transporte



5

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Síntese de Imagens Realísticas

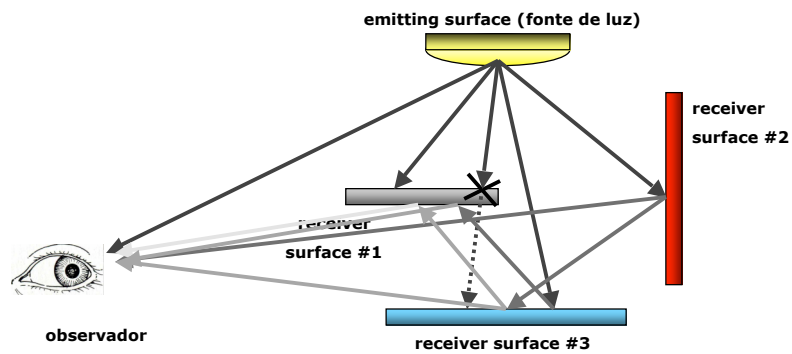
- Geometria
- Materiais
- Luz
- Transporte



6

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Síntese de Imagens Realísticas



7

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Modelos de Iluminação

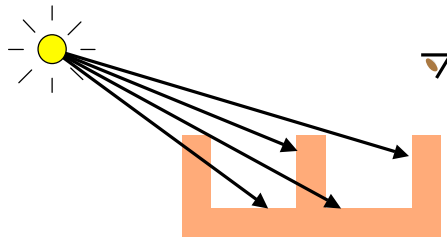
- Descrevem como a luz
 - Interage com os materiais
 - É transportada na cena
 - Atinge o observador
- Categorias
 - Modelos de Iluminação Locais
 - Modelos de Iluminação Globais

8

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Modelos de Iluminação Locais

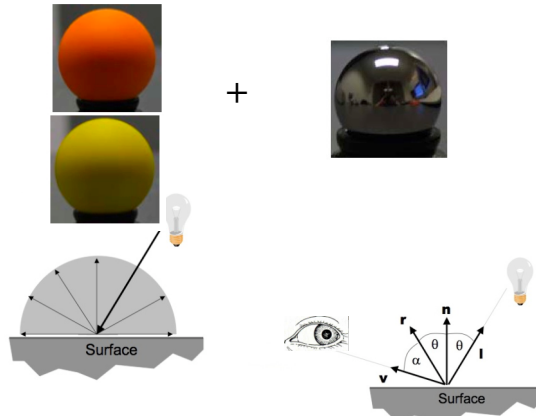
- Rápidos para cálculo
- Não são fisicamente corretos
- Em geral, baixo realismo



9

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Exemplo Phong



$$I = I_a k_a + \sum \{ I_m [k_d (N \cdot L) + k_s (R \cdot V)^q] \}$$

Ambiente

Difusa

Especular

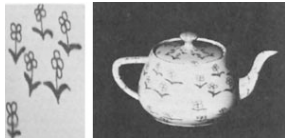
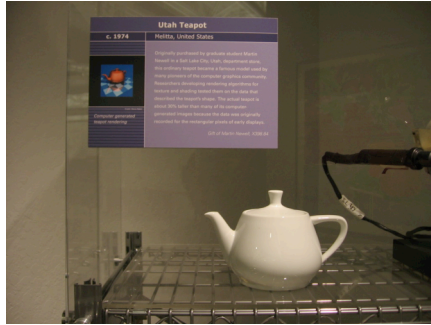
10

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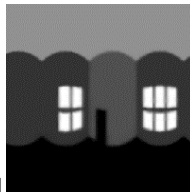
A História do Teapot

Computer Museum

- Adquirido por Martin Newell, aluno em Utah, em 1974
- Por muito tempo o objeto padrão para teste de algoritmos



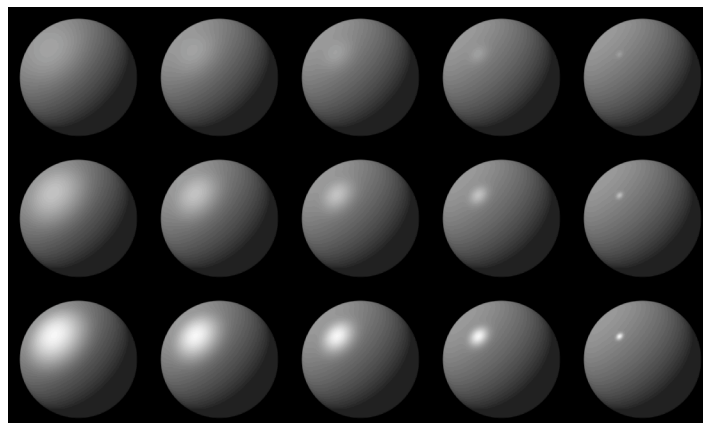
11 Resultados 1978. Tese PhD Catmull



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Exemplo de Phong

$K_d=0.45$



$K_s=0.1$

$q=3$

$q=5$

$q=10$

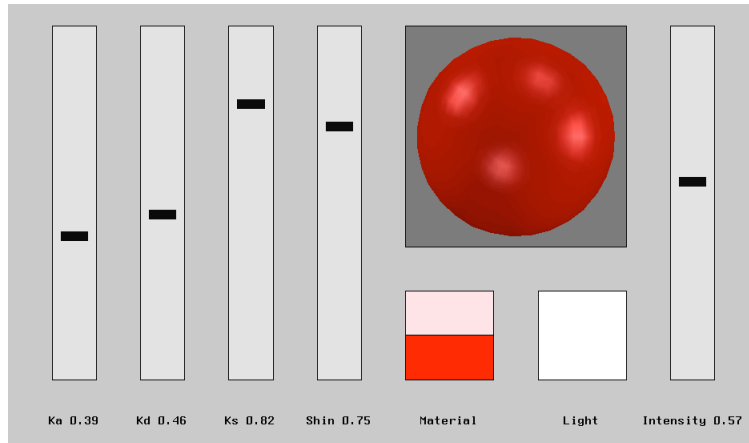
$q=27$

$q=200$

12

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Especificação Usual dos Materiais

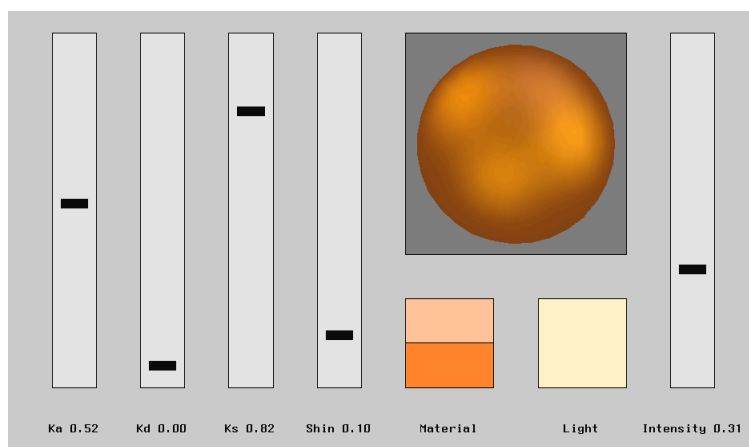


Plástico

13

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Especificação Usual dos Materiais



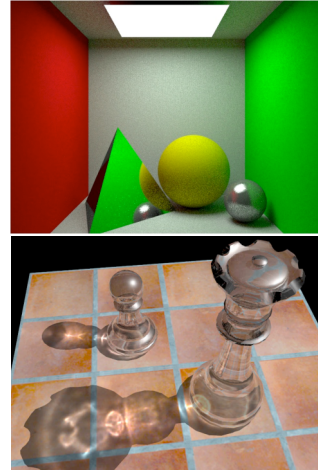
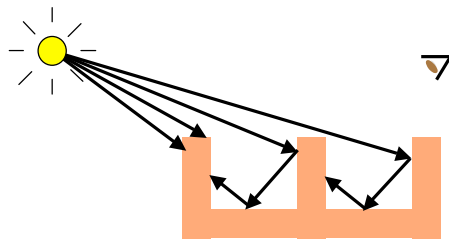
Cobre

14

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Modelos de Iluminação Globais

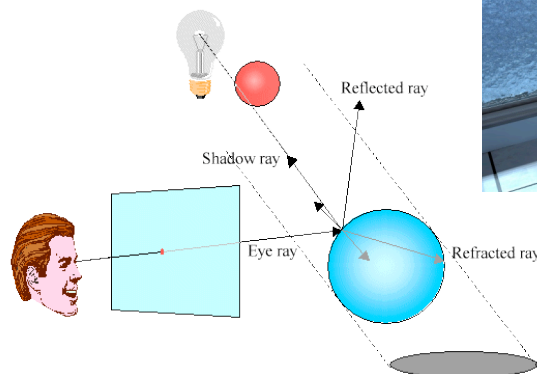
- Toda a cena é considerada
- Maior custo computacional
- Chave para rendering realista



15

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Exemplo Traçado de Raios



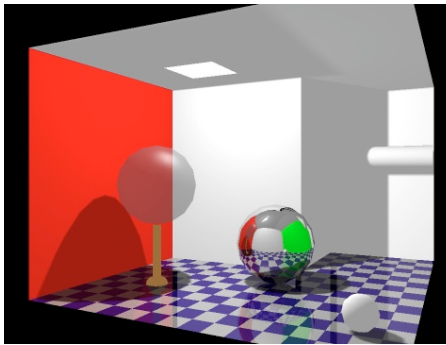
ITRC
Roy Rodriguez
RENDERER USED: Povray 3.6
RENDER TIME: 11h 24min
HARDWARE USED: Turbo 3400+X
AthlonXP 2200+

16

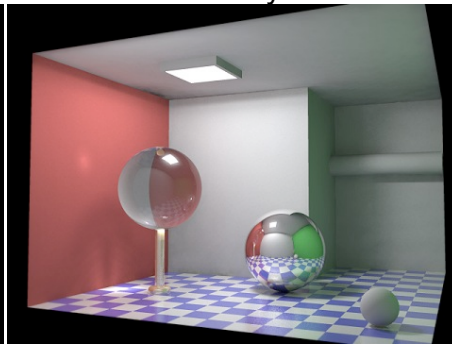
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Comparação

OpenGL



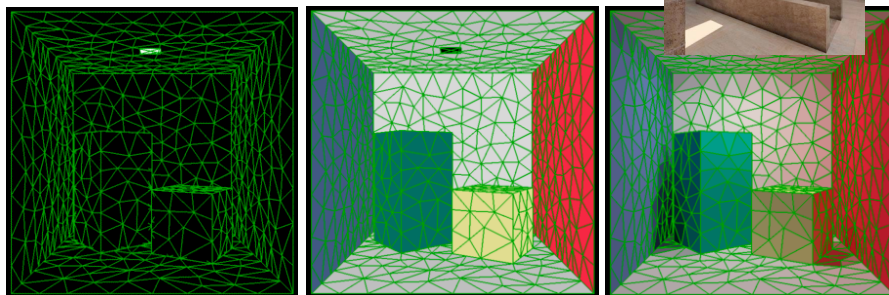
PovRay 3.5



17

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Radiosidade



Fontes de energia

refletividade

Radiosidade total

$$B_i = E_i + \rho_i \sum_j F_{ij} B_j$$

Fator de Forma

18

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The Rendering Equation



- Expressão geral para síntese de imagens [Kajiya86]
- Elegante e compacta :-)
- Qualquer algoritmo de rendering pode ser expresso como uma formulação particular da RE

$$L(x, \vec{\omega}_o) = L_e(x, \vec{\omega}_o) + \int_{\Omega} \rho(x, \vec{\omega}_i, \vec{\omega}_o) L(x', \vec{\omega}_i) V(x, x') G(x, x') d\vec{\omega}_i$$

James T. Kajiya. "The Rendering Equation." Computer Graphics (Proceedings of SIGGRAPH 86). 20(4), pp. 143-150, 1986.

19

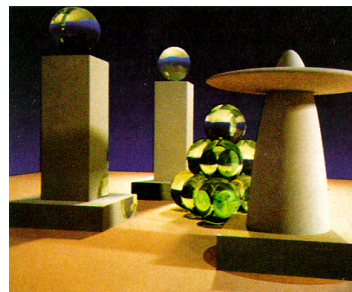
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Resultados do paper original



Figure 5. A comparison of ray tracing vs. integral equation technique. Note the presence of light on the base polygon scattered by the sphere from the light source.

Figure 6. A sample image. All objects are neutral grey. Color on the objects is due to caustics from the green glass balls and color bleeding from the base polygon.



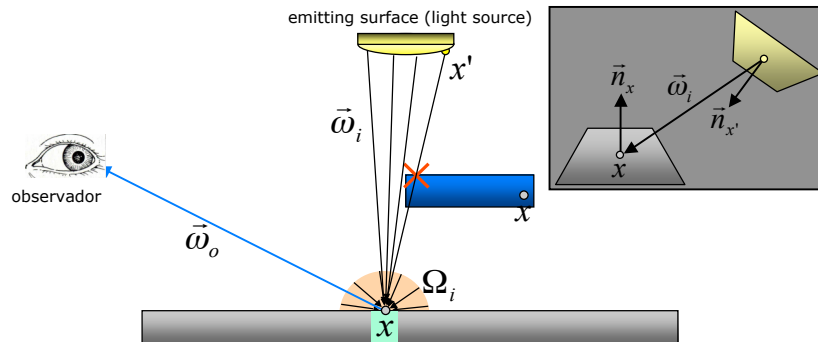
20

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The Rendering Equation

$$L(x, \vec{\omega}_o) = L_e(x, \vec{\omega}_o) + \int_{\Omega_i} \rho(x, \vec{\omega}_i, \vec{\omega}_o) L(x', \vec{\omega}_i) V(x, x') G(x, x') d\vec{\omega}_i$$

material
light
visibility
geometric factor



21

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Observações

$$L(x, \vec{\omega}_o) = L_e(x, \vec{\omega}_o) + \int_{\Omega_i} \rho(x, \vec{\omega}_i, \vec{\omega}_o) L(x', \vec{\omega}_i) V(x, x') G(x, x') d\vec{\omega}_i$$

- Definida recursivamente
- Domínio de integração enorme
- Cálculo caro
- Simplificações para permitir desempenho em tempo real

22

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Algumas outras definições

- Ângulos sólidos
- BRDFs
- Integração Monte Carlo

23

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Angles and Solid Angles

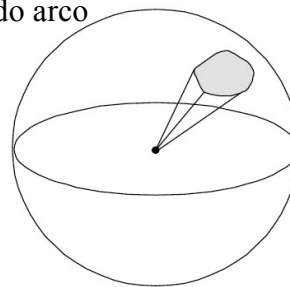
■ **Angle** $\theta = \frac{l}{r}$ ← Comprimento do arco

⇒ circle has 2π radians

■ **Solid angle** $\Omega = \frac{A}{R^2}$

⇒ sphere has 4π steradians

Radianos ao quadrado (sr)



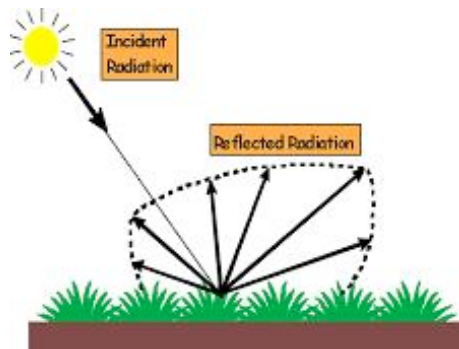
CS348B Lecture 4

Pat Hanrahan, Spring 2002

24

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Intuição sobre BRDF



- ✓ Dada uma direção de incidência de energia luminosa, como a energia é emitida (em que quantidade e em quais direções)
- ✓ **Entendimento da interação entre luz e os materiais**

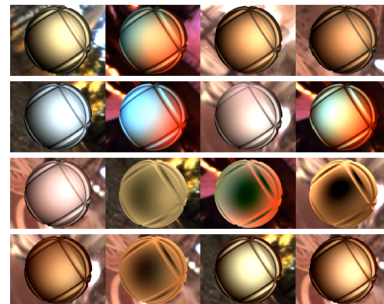
Bidirectional Reflectance Distribution Function

25

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Assunto antigo e atual na comunidade...

Shadowing Dynamic Scenes with Arbitrary BRDFs
D. Nowrouzezahrai, E. Kalogerakis,
E. Fiume
Computer Graphics Forum, 28(2),
Agosto 2009!!



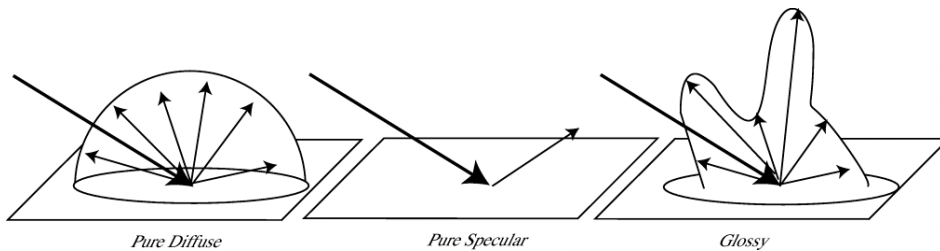
Wavelength Dependent Reflectance Functions. Jay S. Gondek, Gary W. Meyer, Jonathan G. Newman.
Proceedings of SIGGRAPH 94, **July 1994**, pp. 213-220.

26

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BRDF

- Constante de proporcionalidade entre energia incidente e refletida pela superfície



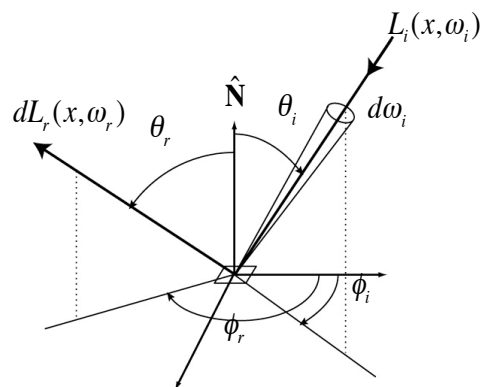
27

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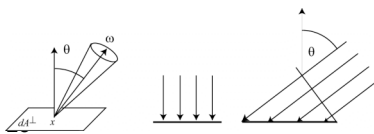
BRDF

Usualmente assume-se que a BRDF é invariante à posição

Função de **5 variáveis**: comprimento de onda, 2 ângulos de incidência e 2 ângulos de reflexão



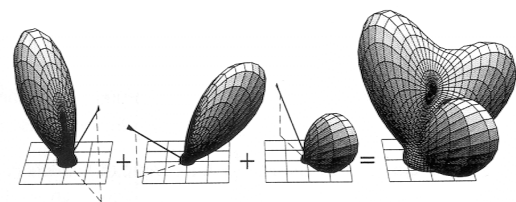
$$BRDF = \frac{L_r(\vec{\omega}_r)}{L_i(\vec{\omega}_i) \cos \theta_i d\omega_i}$$



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Propriedades das BRDF's

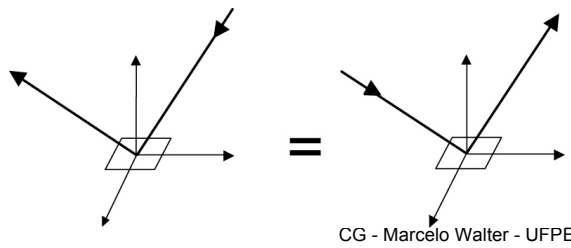
- 1. Linearidade



From Sillion, Arvo, Westin, Greenberg

$$f_r(\omega_r \rightarrow \omega_i) = f_r(\omega_i \rightarrow \omega_r)$$

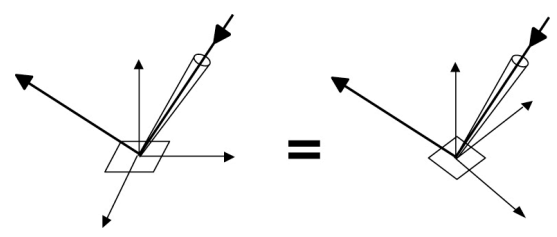
- 2. Reciprocidade



29

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Propriedades das BRDFs



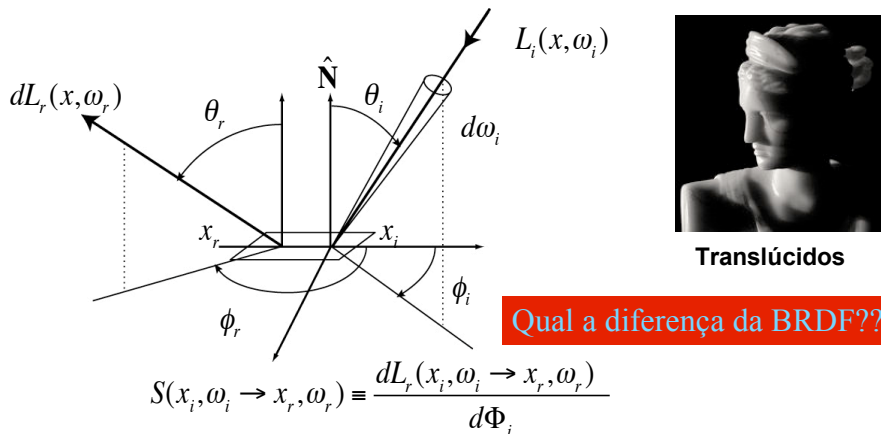
- 3. Isotropic vs. anisotropic
 - Invariante ou não quanto à rotação

30

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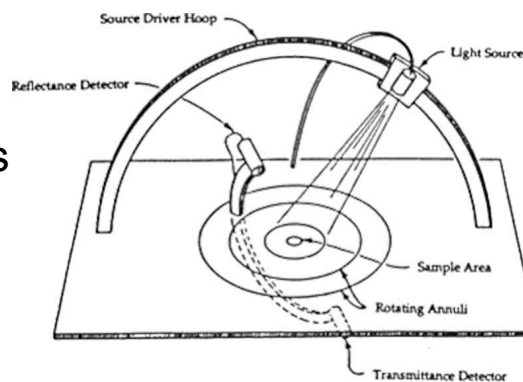
The BSSRDF

- Bidirectional Surface Scattering Reflectance-Distribution Function

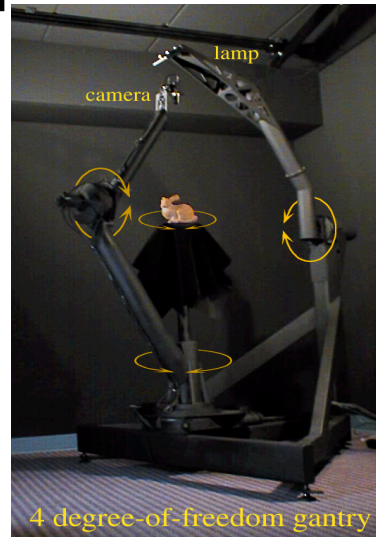
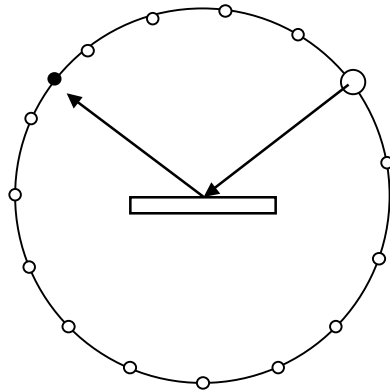


Medindo BRDFs

- Aparelho chamado *Goniorelectômetro*
- As BRDFs medidas podem ser usadas para cálculo de iluminação em modelos empíricos



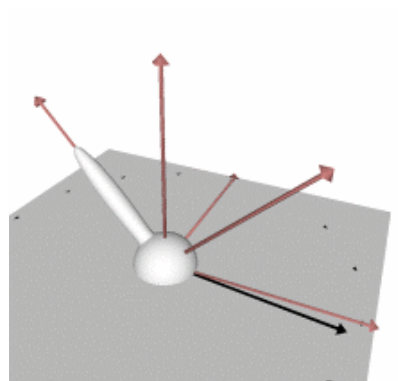
Gonioreflectometer



33

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BRDF para Modelo de Phong



34

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Dupli-color #T-345, Garnet Red.
The lacquer has been coated with
a gloss-reducing finish
Plasti-kote #33, Glass Frosting Spray



Krylon latex enamel #7205, True Blue.
The enamel paint has been coated
with a gloss-reducing finish
Plasti-kote #33, Glass Frosting Spray.



CURET: Columbia-Utrecht Reflectance and Texture Database

*BRDF database with reflectance
measurements for over 60 different samples,
each observed with over 200 different
combinations of viewing and illumination
directions.*

"Reflectance and Texture of Real World
Surfaces,"
K.J. Dana, B. Van-Ginneken, S.K. Nayar,
J.J. Koenderink,
ACM Transactions on Graphics (TOG),
Vol.18, No.1, pp.1-34, Jan, 1999.

Bancos de Dados de BRDFs

■ Factored BRDF Repository

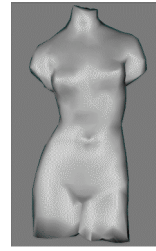
Cornell Garnet Red Duplicolor
T-345 Paint



Cornell Krylon Latex Enamel
#7205, True Blue



Analytic Anisotropic Poulin-
Fournier



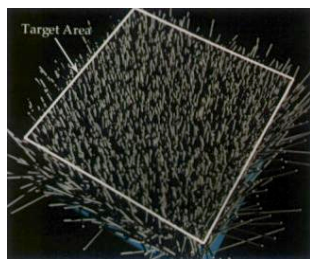
Michael D. McCool, Jason Ang, Anis Ahmad. *Homomorphic Factorization of BRDFs for High-Performance Rendering*. SIGGRAPH 2001, August 12-17, 2001.

<http://www.cgl.uwaterloo.ca/Projects/rendering/Shading/database.html>

37

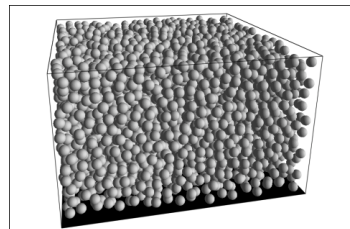
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Modelos Teóricos para BRDFs



Microgeometria do veludo

Westin, S., Arvo, J., and Torrance, K. "Predicting Reflectance Functions from Complex Surfaces", Siggraph 1992.



Microgeometria de tinta

38

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Integração Monte Carlo

- Em rendering, temos necessidade de integração de funções com muitas discontinuidades
- Não conseguimos avaliar estas integrais com regras de quadratura padrão
- A Integração Monte Carlo usa amostragem aleatória da função de interesse para calcular uma estimativa da integral
- Dada uma integral

$$I = \int_a^b f(x)dx$$

Ela pode ser avaliada calculando-se a média μ de $f(x)$ no intervalo $[a,b]$ e multiplicar μ pelo tamanho do intervalo

Método da Amostragem da Média

- Podemos calcular a média dos valores de $f(x)$ em N locais aleatórios uniformemente distribuídos entre a and b
- Isto nos dá uma estimativa Monte Carlo da integral

$$I_m = (b-a) \frac{1}{N} \sum_{i=1}^N f(\xi_i)$$

- Com o aumento de N , a solução fica mais exata

$$\lim_{N \rightarrow \infty} I_m = I$$

- Uma vez que a variância de I_m é $\sigma^2 = \frac{1}{N} \left(\int_a^b f^2(x) dx - I_m^2 \right)$

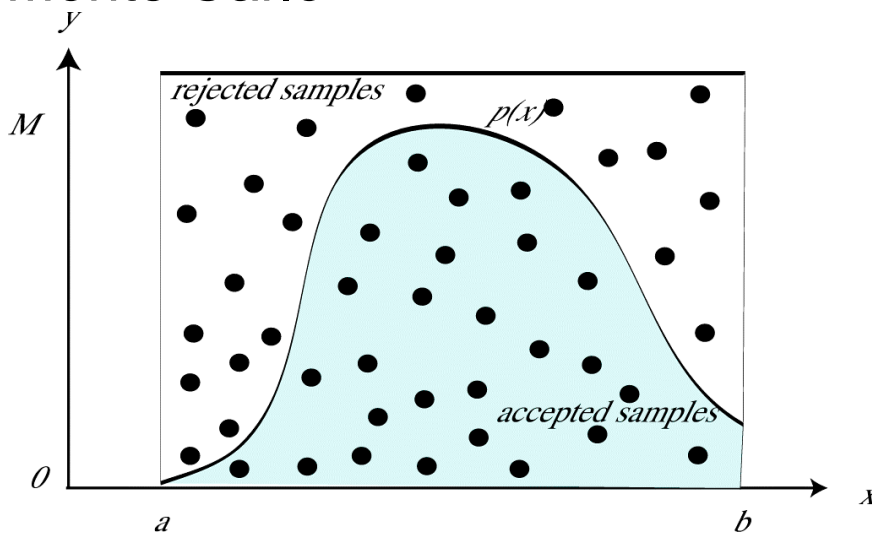
$$\sigma \sim \sqrt{\frac{1}{N}}$$

Para diminuir o erro pela metade, precisamos 4 vezes mais amostras

41

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Monte Carlo

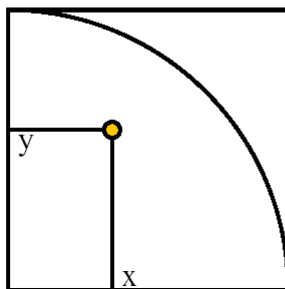


42

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Monte-Carlo computation of π

- Take a square
- Take a random point (x,y) in the square
- Test if it is inside the $\frac{1}{4}$ disc ($x^2+y^2 < 1$)
- The probability is $\pi / 4$



$$\frac{\# \text{ darts hitting shaded area}}{\# \text{ darts hitting inside square}} = \frac{\frac{1}{4} \pi r^2}{r^2} = \frac{1}{4} \pi$$

or

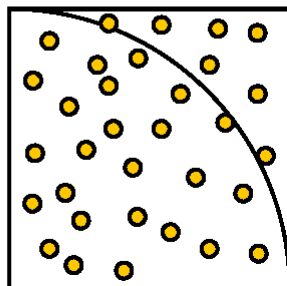
$$\pi = 4 \frac{\# \text{ darts hitting shaded area}}{\# \text{ darts hitting inside square}}$$

43

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Monte-Carlo computation of π

- The probability is $\pi / 4$
- Count the inside ratio $n = \# \text{ inside} / \text{total} \# \text{ trials}$
- $\pi \approx n * 4$
- The error depends on the number of trials



$$\frac{\# \text{ darts hitting shaded area}}{\# \text{ darts hitting inside square}} = \frac{\frac{1}{4} \pi r^2}{r^2} = \frac{1}{4} \pi$$

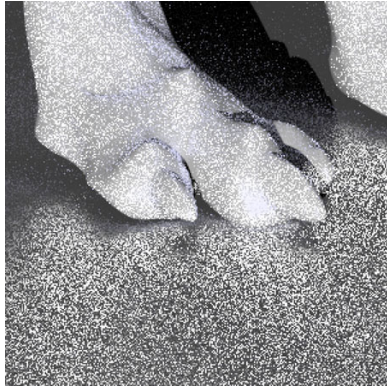
or

$$\pi = 4 \frac{\# \text{ darts hitting shaded area}}{\# \text{ darts hitting inside square}}$$

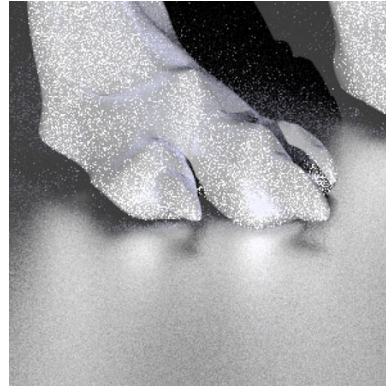
44

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Imagens utilizando integração MC



Variance is perceived as noise



Same view generated using a variance reduction technique

45

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Cáusticas

- Reflexão especular seguida de difusa
- Termina numa superfície difusa



46

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